SEA SURFACE TEMPERATURE, THE RELATIONSHIP BETWEEN ANALYSIS DETAIL AND DATA DENSITY AND DISTRIBUTION - SOUTH CHINA SEA - NORTH-EAST MONSOON

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THESIS

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ABSTRACT

A daily subjective analysis of sea surface temperatures in the South China Sea for three monthly periods during the Northeast (Winter) Monsoon was performed. The analysis model developed showed a three-part division of the South China Sea into a cold eastern side, a warm central region and a cold western side. Bottom topography and surface currents played a major role in delineating analysis patterns. The relationship between data density and distribution and analysis detail was found to be affected adversely by continuity, when data density was small, and by the distribution of the observations, when the data were unevenly distributed. When the area per observation was relatively small and the data were evenly distributed, the number of observations and the number of analysis features which resulted from the analysis had a good linear relationship.

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I. INTRODUCTION

A. STATEMENT OF THE PROBLEM

The purpose of this study was to determine the effect of very dense sea surface temperature (SST) data on daily analysis patterns. Subjective relationships between data density, data distribution, and the amount of analysis detail have been sought.

Normally, only sparse SST observations are available for a particular area and a description of the SST patterns on a day-to-day basis is therefore difficult to obtain. However, due to the increased shipping activity - both civilian and military - in the South China Sea in recent years, sufficient daily observations have been obtained to make a description of daily SST patterns meaningful for that area.

B. APPROACH TO THE PROBLEM

The approach used in this study can be outlined as follows: One would expect that for a given sea surface feature there is a minimum number of SST observations necessary to specify it. Further, there should be a minimum number of SST observations which would bring out all the analysis features for a given area and any observations beyond the minimum number would serve only to support those features. It was apparent that, even though the amount of data for this study was considered dense compared to data available on a daily basis for other oceanic areas, it was not sufficient to establish the minimum number of observations which would show all the features for this area. Therefore, it has been assumed that there is a certain minimum number of observations which would show all features present in a given area, but the minimum number was not reached in this study.

Accordingly, the minimum number of observations necessary to specify a single analysis feature was the aspect upon which the emphasis was placed in this study. A relationship was sought between the number of observations available and the features which appeared in the analysis.

In another somewhat related study, Düing [13] has examined the structure of SST analysis patterns in the Indian Ocean. However, the approach and emphasis differ considerably from those of this study. Düing was concerned with the size of computer contoured analysis features based on mean SST values in one degree squares, and his results cannot be compared directly with the results from this subjective study.

C. DATA SOURCE

Five-day composite SST data for the periods 11 March - 10 April 1969 and 1 November through 31 December 1969 were obtained from Fleet Weather Central Guam (FWC Guam). SST data had been plotted on five-day composite charts in a color code which permitted extraction of daily SST values. The color code used by FWC Guam for the five-day composites consisted of four colors. The first two days of each composite period were indistinguishable from each other and were therefore replotted together. Data for days 3, 4, and 5 could be separated by individual day and were so plotted. In terms of number of analyses, twenty-four charts thus were prepared from a month's data. This method of handling the data was not considered biasing to the study since the stated purpose was to treat the observations in as small a time frame as possible - daily if the data were available.

Table I is a breakdown of the number of observations which were analyzed. No attempt was made to evaluate the accuracy of the observations reported nor to weight them in accordance with the method by which they were obtained (i.e., injection

TABLE I

SUMMARY OF OBSERVATIONS

PERIOD	NUMBER OF OBSERVATIONS	OBSERVATIONS PER DAY			OBSERVATIONS REJECTED	
		AVERAGE	HIGH	LOW	NUMBER	PERCENT
11 Mar-10 Apr	2,833	91	152	35	7	0.25%
1-30 Nov	1,950	65	98	26	11	0.56%
1-31 Dec	1,946	63	102	23	29	1.49%
Totals	6,729	73	152	23	47	0.69%

thermometer, bathythermograph, XBT, etc.). However, data with obvious errors due to coding and/or transmission were disregarded in the analyses. The percentage of data rejected by this criterion was very small - less than one percent. (See Table I.).

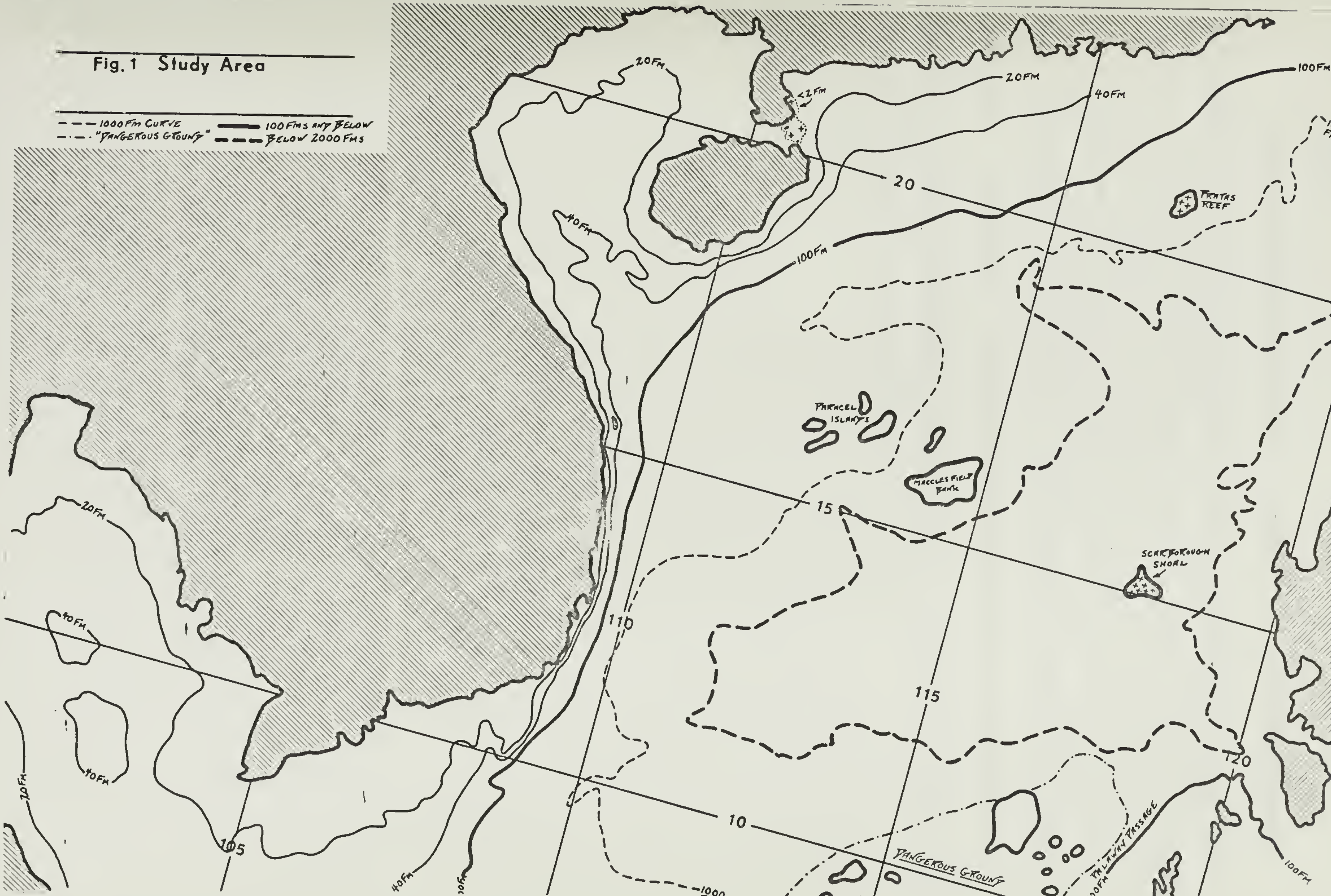
D. DESCRIPTION OF THE STUDY AREA

The South China Sea embraces an area of 1.8×10^6 square nautical miles. This largest of the marginal seas in the western Pacific is bordered on the west by Vietnam, by the southern limit of the Gulf of Thailand and by the Malay Peninsula; on the east by Formosa, the Philippines and Borneo; on the north by China; and on the south by the rise between Sumatra and Borneo (about 3S). The specific part of the South China Sea which was involved in the study is shown in Figure 1. This chart is the area of the South China Sea on operational synoptic weather charts of FWC Guam.

1. Bathymetry

The major topographical feature of the South China Sea is a rhomboid-shaped basin with depths in excess of 2000 fathoms. (See Figure 1.). Reef-studded shoal areas occur within the basin, e.g. Macclesfield Bank and Scarborough Shoal. Along the northwest side of the basin a shelf extends about 150 nautical miles offshore and includes the Formosa Strait and the Gulf of Tonkin. The islands of Hainan and Formosa are situated on this shelf. The Gulf of Tonkin gradually deepens toward the center reaching a maximum depth of less than 50 fathoms. The main entrance to the South China Sea from the Pacific Ocean is by way of the deep Bashi Channel (north of the Philippines), where most of the water exchange takes place. Relatively little water is transported through the other connecting channels, on the south, east and west, due to shallow sill depths.

Fig. 1 Study Area



2. Climate

The period covered in the study was the end of the Northeast Monsoon (cold season) of one year and the first part of the Northeast Monsoon of the following year. Typically, during the Northeast Monsoon, cold air moves from its Siberian source equatorward as a high pressure system around which the winds circulate clockwise. Off Vietnam, this circulation is characterized by winds having a northeasterly component. The surface air of the Northeast Monsoon flows southwestward gaining heat from the warmer surface of the South China Sea. This situation creates a semi-permanent cloud cover extending down to near 15N. [5].

II. BACKGROUND

A. SEA SURFACE TEMPERATURE ANALYSES

Sea surface temperature (SST) is one of the most easily measured oceanic properties and one of the few properties reported on a synoptic basis. SST is indicative of other conditions and processes in the sea. The value of the knowledge of SST distribution in synoptic oceanography has been well established, especially as applied to navigation, naval operations, weather forecasting and fisheries problems.

The factors determining and modifying the surface temperature distribution and subsurface thermal structure may be divided into five groups: (1) heat exchange, (2) convective mixing, (3) advection, (4) mechanical mixing and (5) factors usually of a local nature, such as runoff, tidal currents, and upwelling. [6] For this study of the South China Sea, emphasis was placed on the last two of the factors listed, since extensive meteorologically motivated studies of the other factors have been made. [See especially 5, 6, and 9]. Numerous charts of long-term monthly average SST's have been published which depend primarily on the period of the data collected and the averaging techniques used. None of these "mean monthly" presentations takes into account relatively sudden changes in SST which can be caused by any of the five factors listed above. According to Wolff [6], the greatest variations in SST are caused frequently by advection due to wind-driven currents. Table 2 shows the percent frequency of north or northeast winds and the percentage greater than 25 knots at Pratas Reef (see Figure 1) for the months of November and December. [5]

TABLE II

PERCENT FREQUENCY OF NORTH OR NORTHEAST WINDS AT PRATAS REEF

	NOV	DEC
N/NE Winds (%)	86	80
%>25 knots	63	52

B. SEA SURFACE TEMPERATURE - SOUTH CHINA SEA

The values and variations of temperature in the waters of the South China Sea are affected primarily at the surface by the monsoons and at depth by the bottom topography. [9] The surface temperature decreases northward. It is lowest in January and February, when the circulation induced by the winter monsoon (Northeast Monsoon) drives the cold waters southward; and highest in August, when the summer monsoon (Southwest Monsoon) reverses the current pattern and insolation is at a maximum. As a result, surface temperatures are most variable in the shallow extreme northern portions of the South China Sea. The mean annual range of surface temperature is about 32° F, and in exceptional years, the range can be as large at 40°F. However, in the southernmost portions of the South China Sea, the annual variability in SST rarely exceeds 3° F. [9].

1. Mean Monthly Conditions During the Period of the Study

The mean monthly sea surface temperature conditions for the South China Sea have been taken from the FWC Guam Oceanographic Outlook for the months of March, April, November and December. During March, the SST maximum varies from less than 70° F along the Vietnam coast and in the Gulf of Tonkin to 83° F south of 10N. Isotherms are oriented generally SW to NE. During April, there is a period of general warming as the Northeast Monsoon season comes to an end. South of 15N, the SST has the value of 82-84° F. In the Gulf of Tonkin and northern regions, the

SST varies between 75-77°F. During November, the prevailing Northeast Monsoon causes the surface waters to cool due to decreased insolation caused by the semi-permanent cloud cover extending down to 15N. [5] In addition, during the winter monsoon, evaporation exceeds precipitation, heat is conducted to the colder atmosphere from the warm surface waters below, and wind mixing extends down through the thermocline. SST varies between 79-83°F in the central regions compared with values of 70-75°F along the China coast. During December, the Northeast Monsoon continues to cool the South China Sea. The SST is between 75-80°F in the central regions and 68-73°F along the China mainland. The December SST in the Gulf of Tonkin is about 68-75°F. [1, 2, 3, 4]

III. DATA TREATMENT AND PRESENTATION

A. ANALYSIS PHILOSOPHY

In analyzing the sea surface temperature charts, the following principles were observed:

1. All observations were considered valid, except the very small percentage noted in Table I.

2. All valid observations were drawn to in the analysis.

3. Continuity was taken into account but it was not the determining factor. In order not to filter out the daily changes, a moderate degree of change was permitted on consecutive charts.

4. Analysis features were related to the bottom topography and surface currents.

5. Excessive "tonguing" of analysis features was avoided except in the Tonkin Gulf sub-region where the dense data required, at times, very complicated and specific analysis patterns. (See Figure 2 for a sample SST Analysis).

B. ANALYSIS PROCEDURE

Seventy-two separate analyses were prepared for the study period using bottom topography and surface current charts as underlays in the interpretation of the data. Bottom topography and surface current charts were used as underlays:

1. To permit isotherms to be drawn around islands and reefs - an important factor considering the highly irregular topography of the South China Sea.

2. To allow relatively small irregular features to be drawn in shallow water depths when the number of observations permitted.

3. To allow isolated features to be drawn when the surface current patterns indicated a feature could have been broken off and isolated by a surface current eddy.

Figure 2:

SST ANAL

DATE: 25 MAR 69

4. To impart a reasonableness to the entire analysis; for, like Düing [13], it was assumed that the sea surface temperature patterns were linked to the wind driven surface circulation.

C. ANALYSIS FEATURES AND SUB-REGIONS

After the analyses were prepared, carefully checked and reviewed, a determination was made of the number of analysis features present with the corresponding number of observations for each chart for each sub-region. (sub-regions are indicated in Figure 3). Any discernible crest or trough and any closed isotherm was designated an analysis feature. Figure 4 is an example of how the number of analysis features were counted for three sub-regions on the actual analysis chart for 15 March 1969.

Answers to the following questions were sought:

1. Does data density and distribution determine the analysis detail?, and the corollary

2. If one adds/removes data, does one get more/less analysis detail?

To answer these questions, for each of the three monthly periods of the study, the number of observations in each sub-region which went into analyzing a particular number of features was averaged and plotted against that number of features. The total number and the variability of the observations (standard deviation) were also indicated. In addition, the frequency of occurrence of a particular number of features during the monthly period was plotted on the same graphs. (See Figures 5, 6, and 7).

The area (in square nautical miles) of each sub-region was determined from standard U.S. Navy Hydrographic Office charts and the area per observation for each day in each sub-region was then calculated. (See Appendix C). For each of

Fig. 3: SUB-REGIONS

(area in sq. naut. miles)

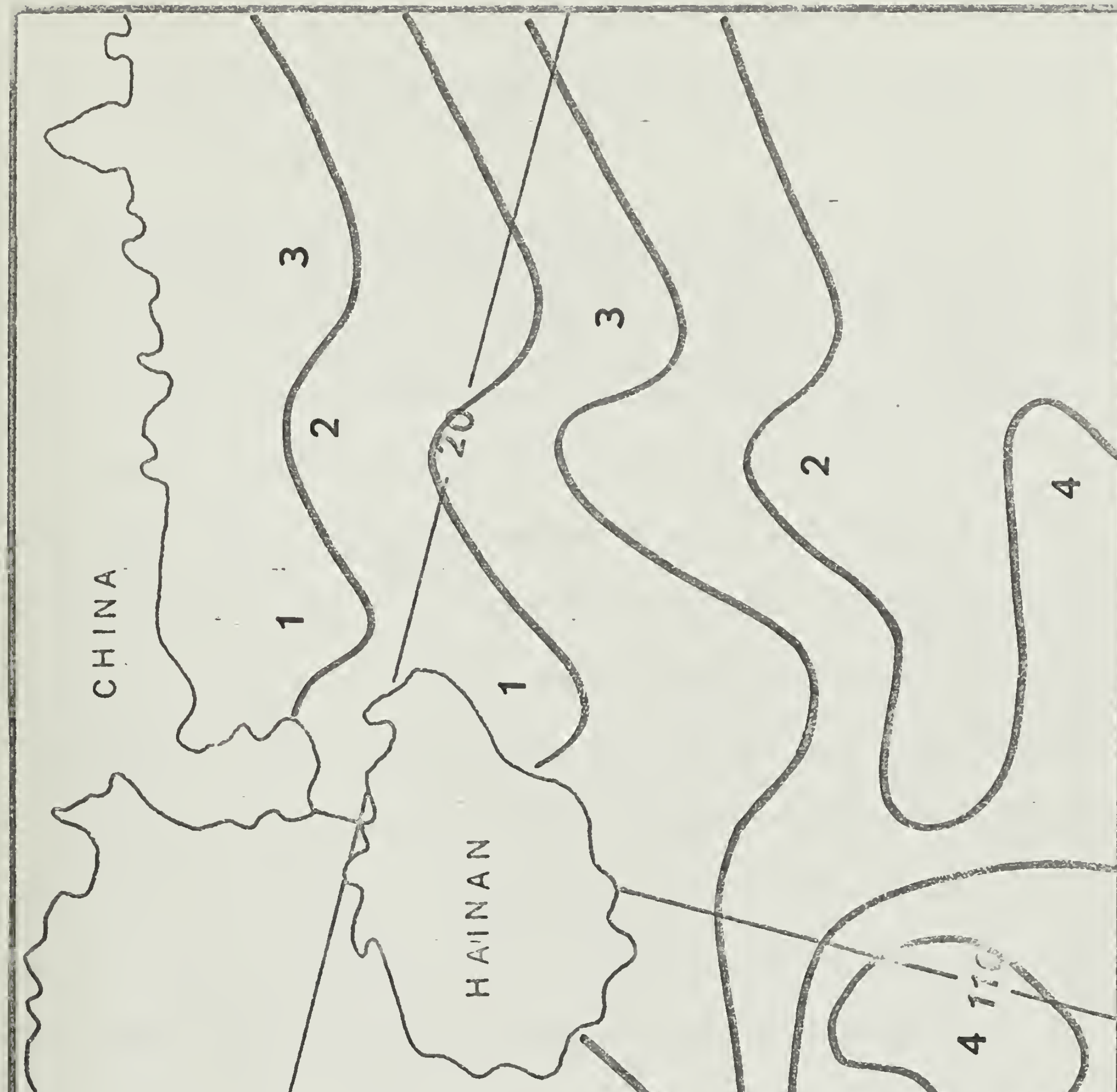


Fig. 4: Example of How Features Were Counted

the three monthly periods of the study, the area per observation per day was averaged and plotted against the average number of observations for that sub-region. (See Table III and Figure 8).

D. COMPARISON WITH OTHER ANALYSES AVAILABLE

Two sources of analyses were available for comparison with the analyses of this study, the mean monthly analyses based on a climatological approach to the data [12], and daily operational analyses of FWC Guam for the period 11 March - 10 April 1969. FWC Guam's analyses were not influential in the formation of those of this study because they were not available to the author until after the present analyses were completed. A relation between analysis features and data density and distribution was sought. Also, the method by which FWC Guam utilized bottom topography and surface current information in making the analyses was examined. Additionally, FWC Guam layer depth and below layer gradient synoptic charts for the same period were studied to see if a relationship existed between them and the SST analyses - both those prepared by Guam and those of the present study.

IV. RESULTS

A. ANALYSIS PATTERNS

The seventy-two analyzed sea surface temperature charts prepared showed one overall common characteristic, a three-part division of the South China Sea into a cold western side, a warm central portion, and a cold eastern side. (See Appendix B for sample analyses). The three parts were oriented generally SW to NE. The topographical arrangement of the South China Sea actually lends itself to the three-part characteristic indicated in the analyses. The cold saline surface water of the Pacific Ocean comes into the South China Sea via the Bashi Channel [10], is picked up by the monsoon-induced surface currents, swept counterclockwise around the top of the South China Sea, and moves down the coast of Vietnam picking up the cold less saline water moving out of the Tonkin Gulf as it goes. The maximum surface current velocities are experienced along the coast of Vietnam. (See Appendix A.).

The cold eastern side of the South China Sea is characteristic of a deep water mass with relatively low surface current velocities which maintains a more or less permanent equilibrium adjusting by convective processes for the warmer surface water advected slowly from the south.

The warm waters advected from the south are confined to a warm tongue extending up into the west central region of the South China Sea. Relatively shallow waters, low surface current velocities, and numerous islands and shoal areas help to keep the surface temperatures in this central area warm.

The three-part characteristic indicated that one major wave length was present with various smaller wave lengths superimposed on it. The smaller wave lengths were

affected by the character of the monsoon (since the monsoon determines cloud cover, wind direction, and the amount of runoff), but more importantly, the smaller wave lengths appeared to be caused by the irregularities of the bottom topography and surface current eddies, especially off the coast of Vietnam.

B. ANALYSIS DETAIL AND DATA DENSITY AND DISTRIBUTION

Figures 5, 6 and 7 represent the relationship by sub-region of the number of observations to the number of features analyzed. The relationships were considered either good or poor using the following criteria:[1]

good - the number of features showed a linear increase with increasing number of observations; standard deviations were included in determining the linear character of the plot; in some cases, one or , at most, two data points were omitted; in all cases where data points were omitted, the data point had a frequency of occurrence of one.

poor - no consistent pattern of the data points was discernible.

A good linear relationship existed between the number of observations present and the number of features analyzed when the area-to-observation ratio was relatively small and the data were more or less evenly distributed throughout the sub-region.

Sub-region 'a' indicated a good relationship for each of the three monthly periods of the study. The data in Sub-region 'a' were relatively dense and evenly distributed. Sub-region 'a' contains the main shipping lanes in the South China Sea - both

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[1] There should be a minimum number of SST observations which would bring out all the analysis features for a given area. On reaching this minimum number of observations, the relationship between observations and features will cease to be linear. The number of features will remain constant while, theoretically, the number of observations will increase without bound. This minimum number of observations was not reached in this study and, therefore, only the linear part of the relationship is considered.

north-south and east-west. It is unencumbered by any large islands or shoal areas. Three to six analysis features occurred most frequently.

Sub-region T also indicated a good relationship. In two of the three monthly periods studied, Sub-region T had more observations than Sub-region 'a'. Sub-region T also indicated a good distribution of data was present although the area north of 20N was not always covered very extensively. Four to seven analysis features occurred most frequently.

For the three monthly periods of the study, Sub-region W indicated the best relationship between the number of observations and features analyzed. The standard deviations of the data points were the smallest of any other sub-regions and from one to four analysis features occurred most frequently. Sub-region W was the smallest sub-region in total area but nevertheless the observations were dense and distributed evenly - probably due to the large amount of coastal ship traffic moving in the sub-region.

Slopes of the lines drawn through the data points of the figures for Sub-regions 'a', T and W were between 0.4 and 1.7. (The average slope was 0.9).[2]

Sub-regions 'c' and N indicated a poor relationship between the number of observations and features analyzed for each of the three monthly periods of the study. These two sub-regions had the smallest data density not only because the main shipping lane of the South China Sea passes only through the very eastern side of Sub-region N

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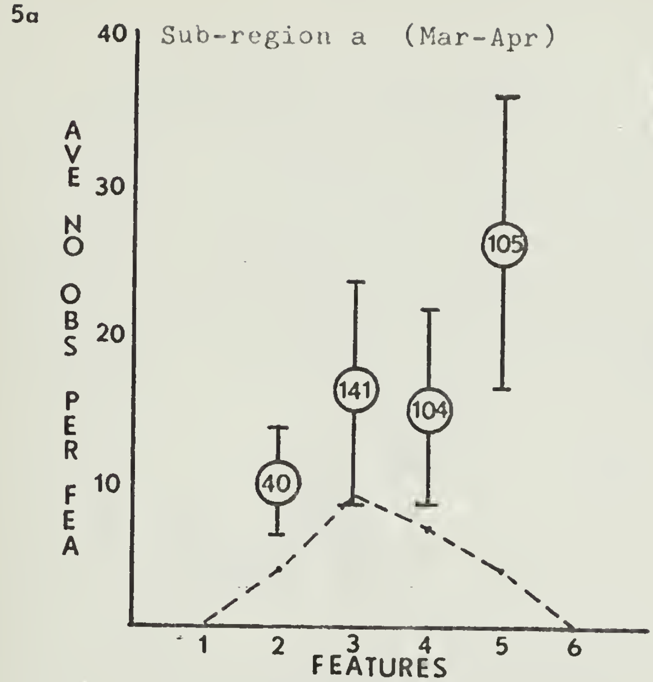
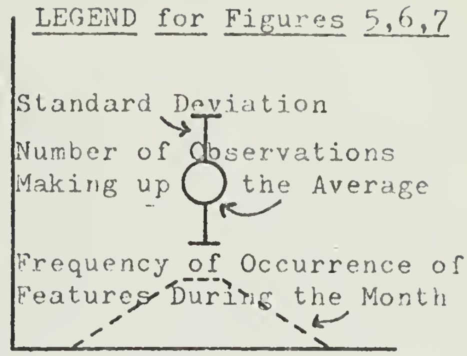
[2] The line drawn through the data points from which the slope was determined included subjective considerations of the standard deviation of the data points, the total number of observations making up each data point, and the frequency of occurrence of the feature during the monthly period. At times, one or two data points had to be disregarded. The disregarded data points were, in all cases, those which had a frequency of occurrence of one.

and the northwestern corner of Sub-region 'c', but also because the military shipping in the South China Sea did not concentrate in these areas and further reduced a potential source of data. Sub-region 'c' has extensive shoal areas and Sub-region N contains Pratas Reef. Slopes of the lines drawn through the figures for Sub-regions 'c' and N have a maximum value of 0.1. (Most figures had no slope).

The sub-regions which indicated a poor relationship between the number of observations and features analyzed plotted above the 11,5000 sq. n.m. line on Figure 8 where the average number of observations per day was between four and nine. This indicates that in areas of about the same size (for example, Sub-regions a, b, c, d and N) greater than nine observations per day were needed to specify the analysis features for that area. (Sub-region N which has an area of about 74,000 sq. n. m. appears close enough in total area to include in the comparison above.).

Sub-region 'b' for November (Figure 6b) was the only poor sub-region which plotted below the 11,500 sq. n. m. cut-off line on Figure 8. A possible explanation for this is, although the data were relatively dense, the distribution was uneven. It is Sub-region 'b' that contains the Paracel Island and Macclesfield Bank which cause shipping traffic to be diverted around them and hence SST observations to be distributed unevenly in the sub-region. (Sub-region 'b' for December was in the poor category and plotted with the cluster of other poor sub-regions on Figure 8. Sub-region 'b' for March-April showed a relatively good relationship but had over a hundred more observations than in November which were evidently distributed sufficiently for an observation-to-feature relationship to result).





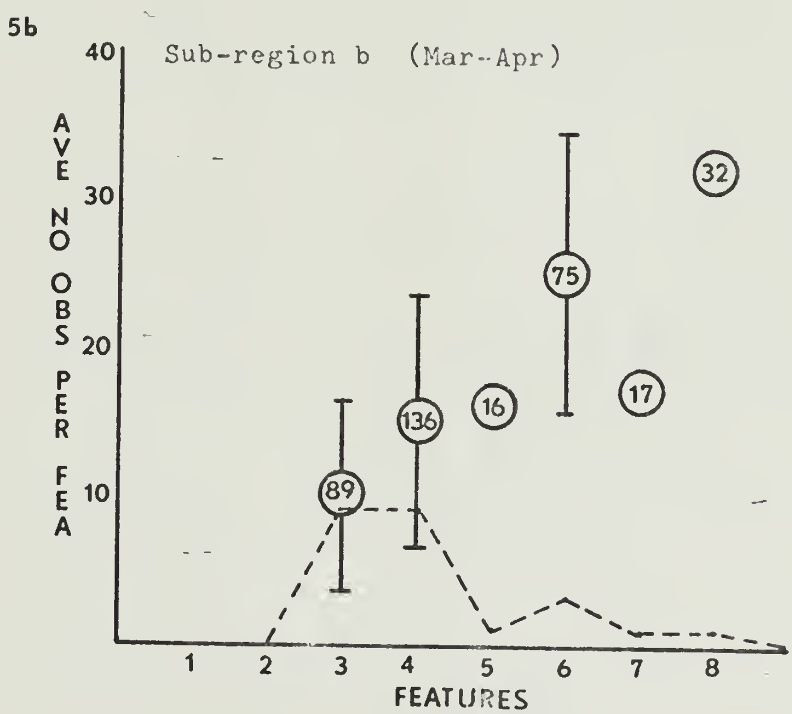
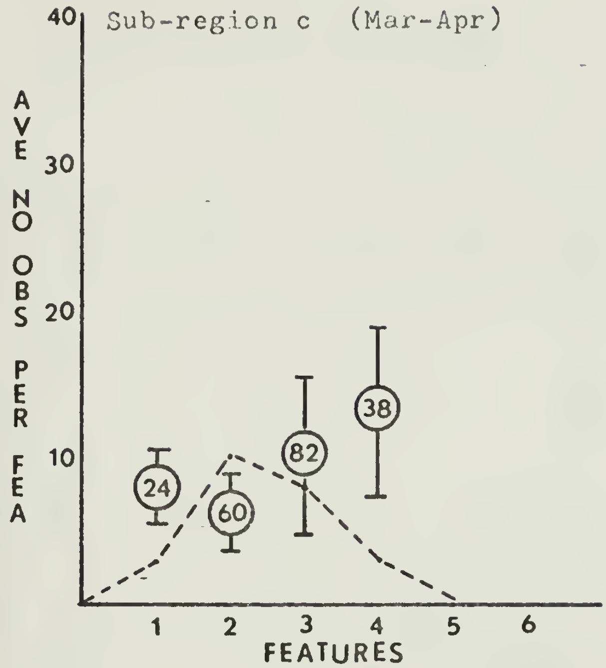


Figure 5: Monthly Average of the Number of Observations per Fe ture vs Features (March–April)

5c



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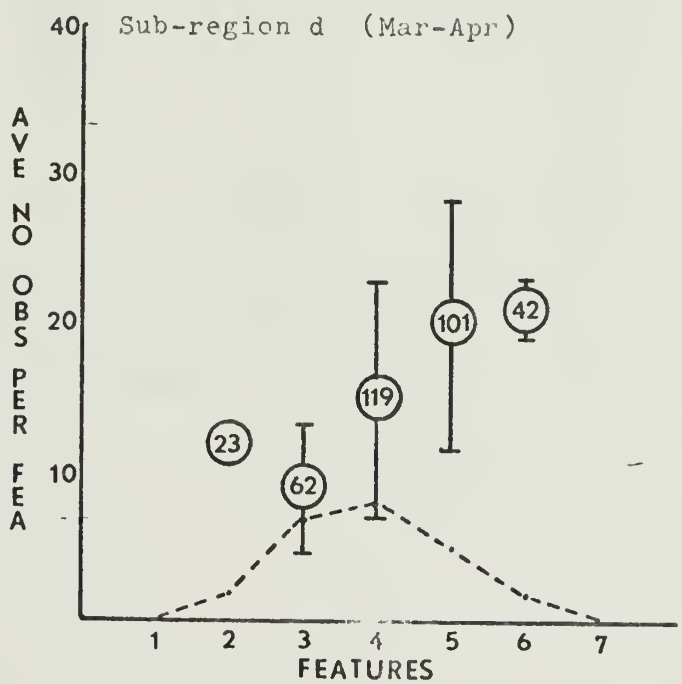
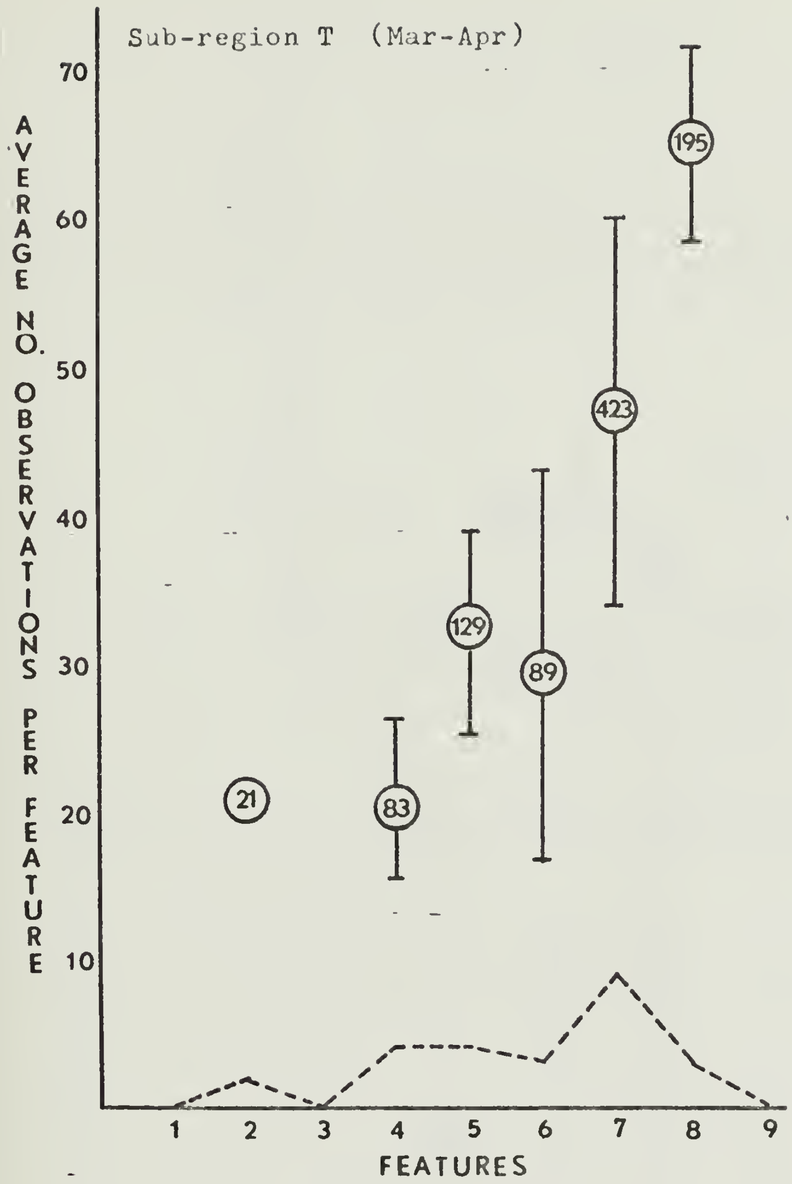


Figure 5: Monthly Average of the Number of Observations per Feature vs Features (March-April)

5e



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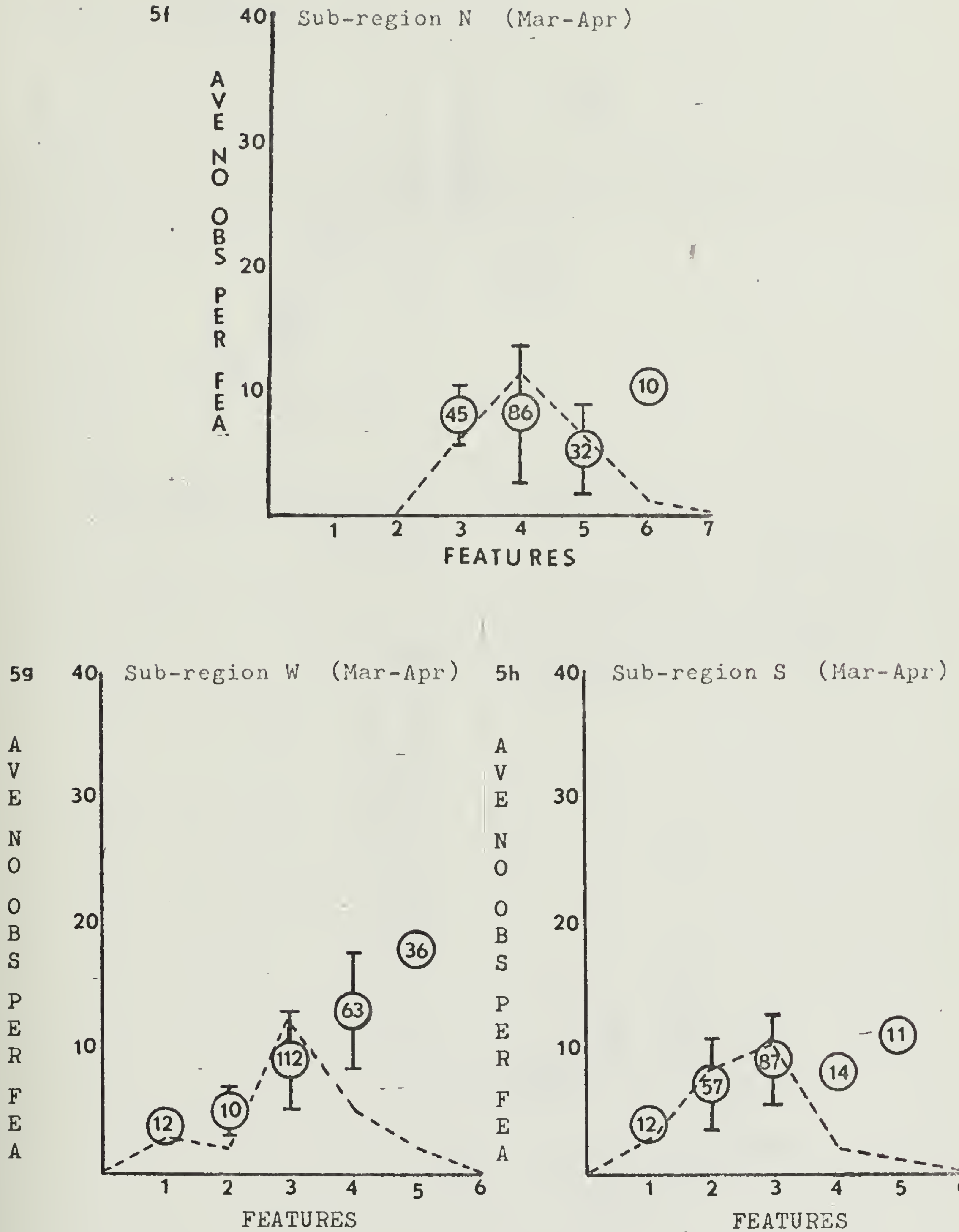

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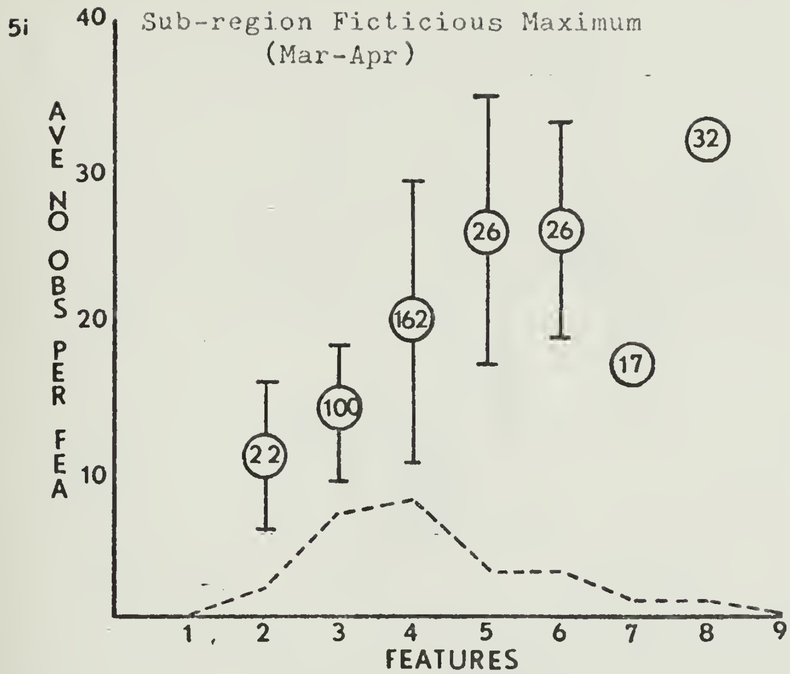

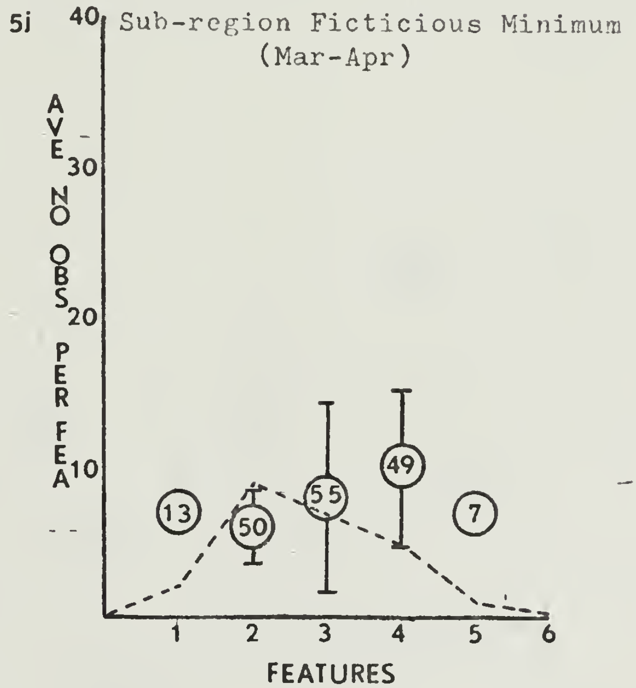

Figure 5: Monthly Average of the Number of Observations
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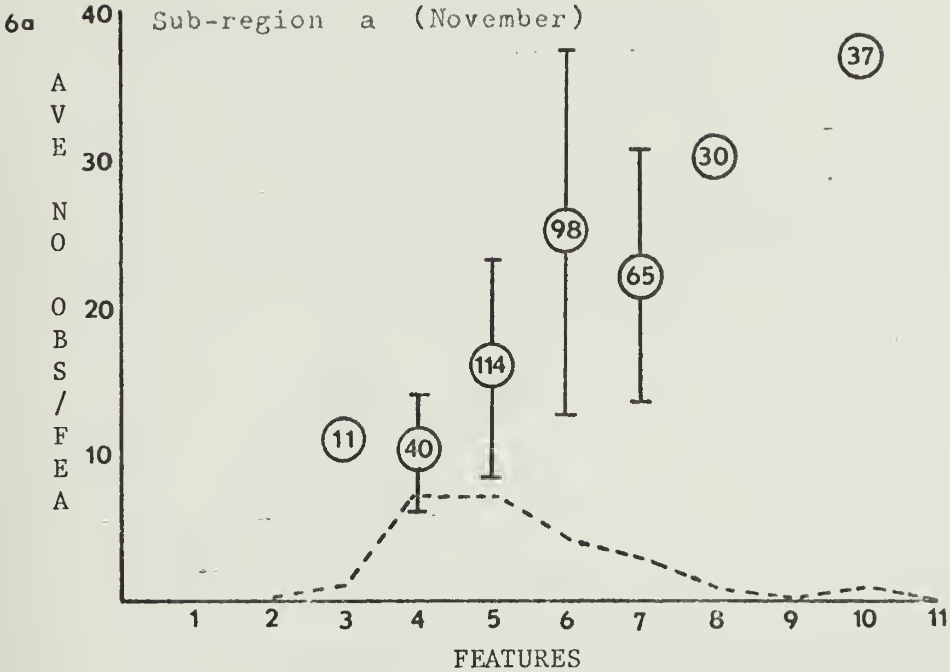


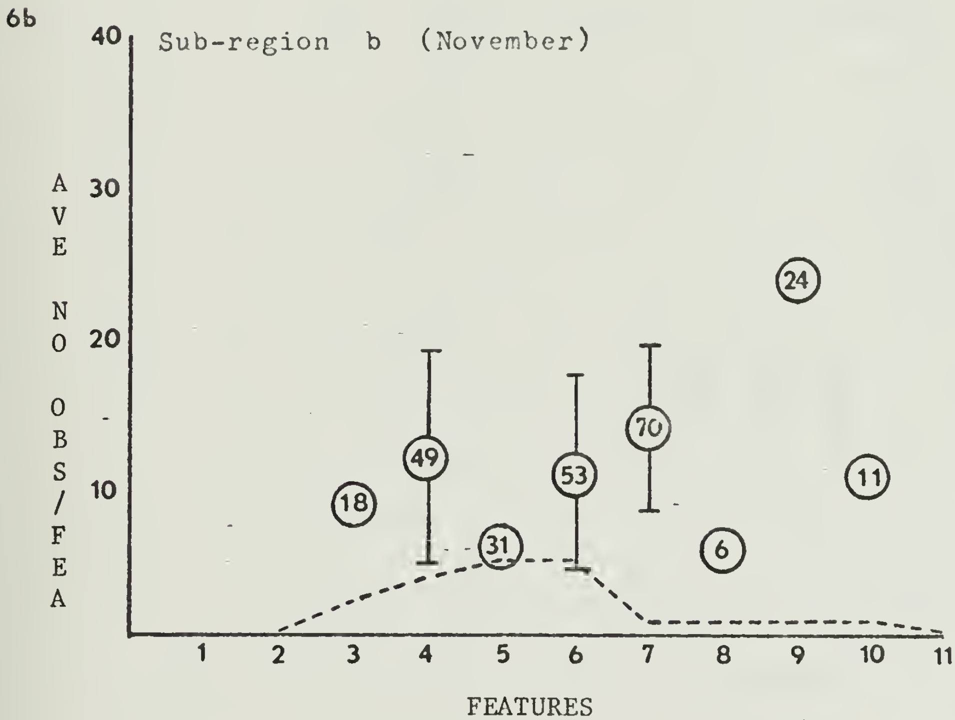
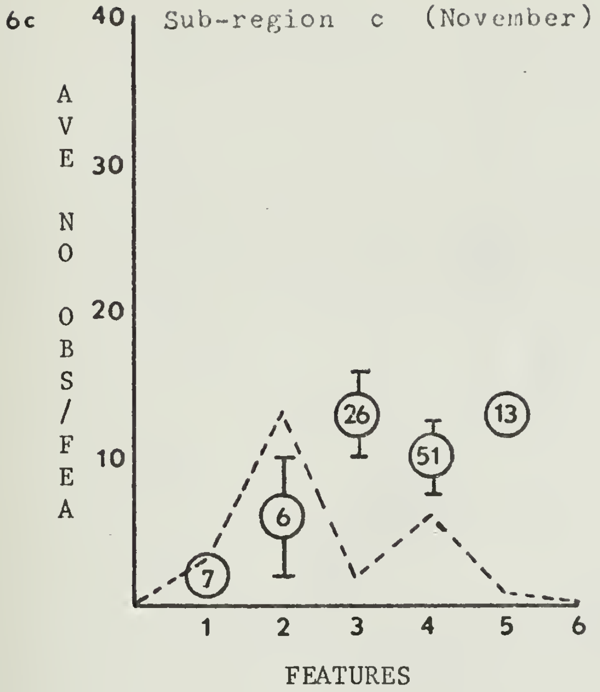


Figure 6: Monthly Average of the Number of Observations per Feature vs Features (November)



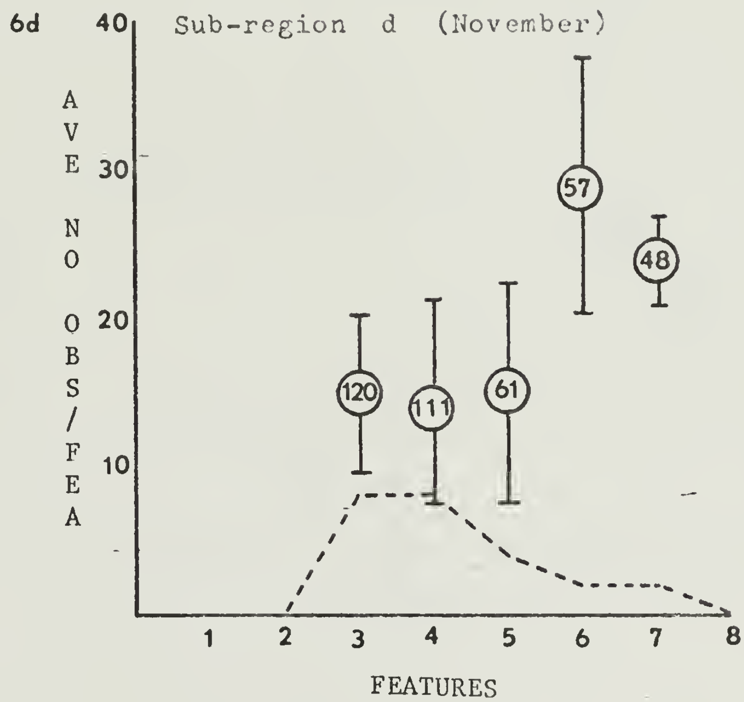
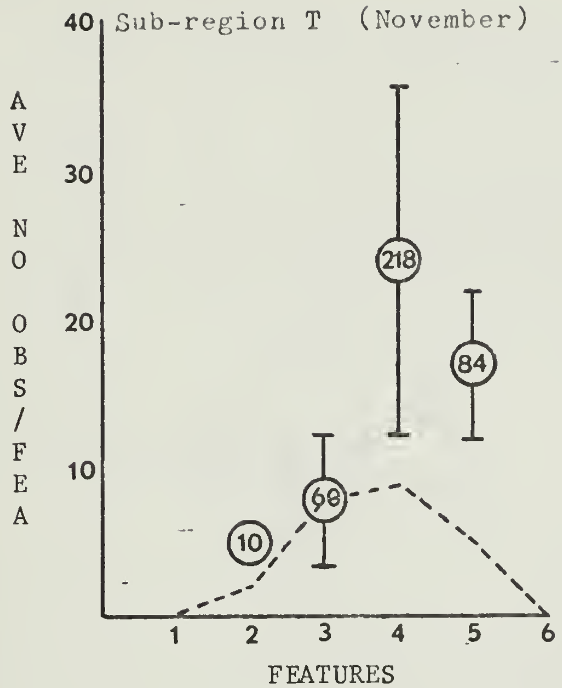


Figure 6: Monthly Average of the Number of Observations per Feature vs Features (November)

6e



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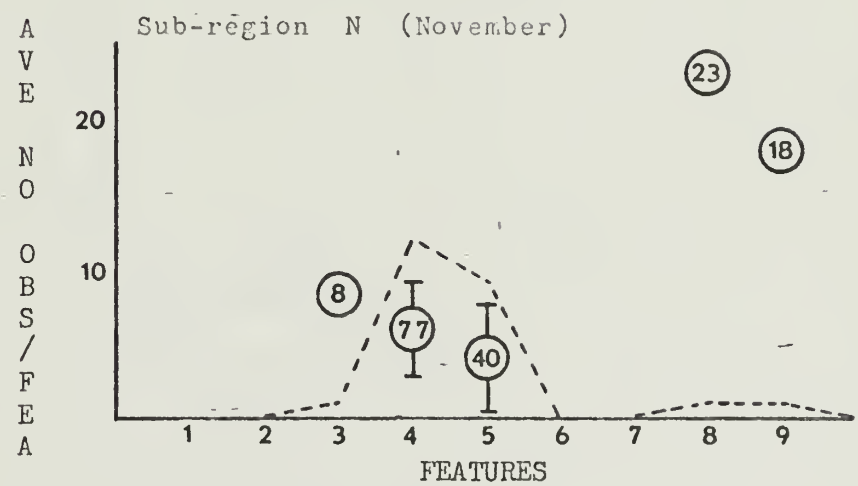
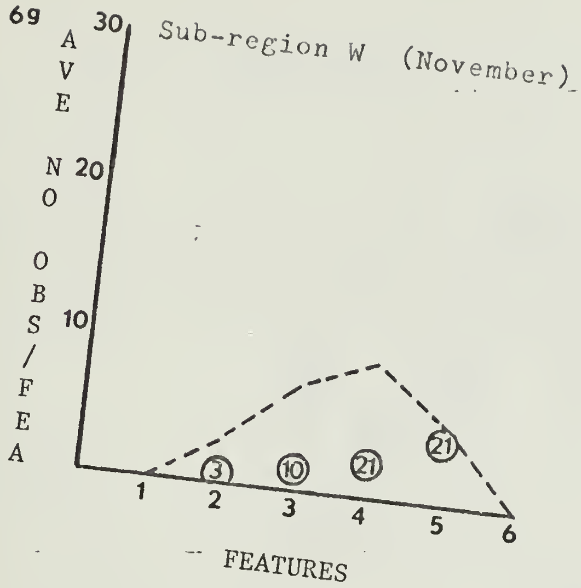


Figure 6: Monthly Average of the Number of Observations per Feature vs Features (November)



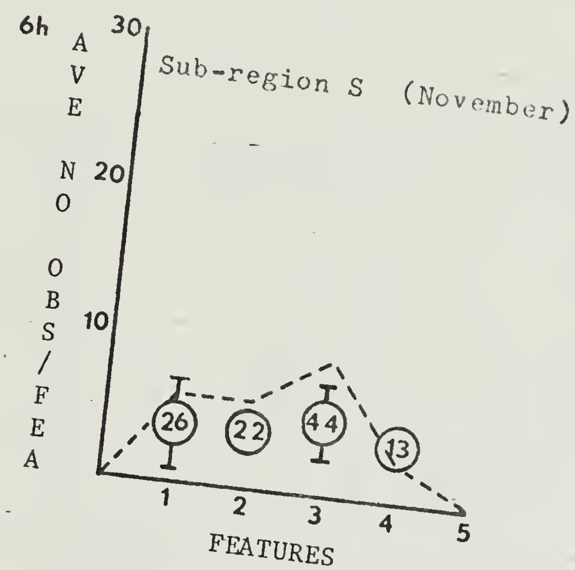
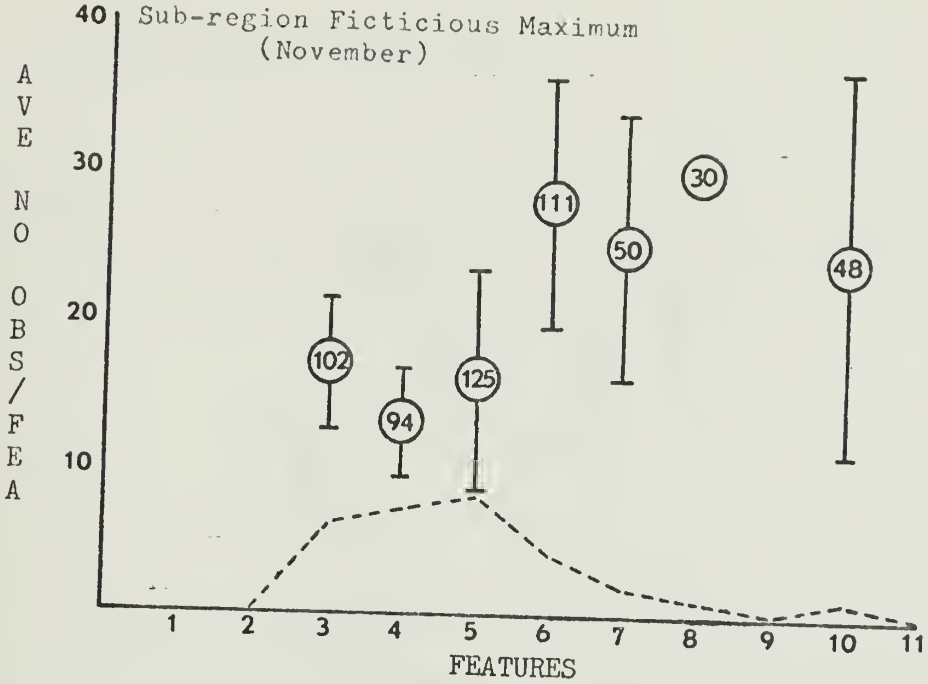


Figure 6: Monthly Average of the Number of Observations per Feature vs Features (November)

6i



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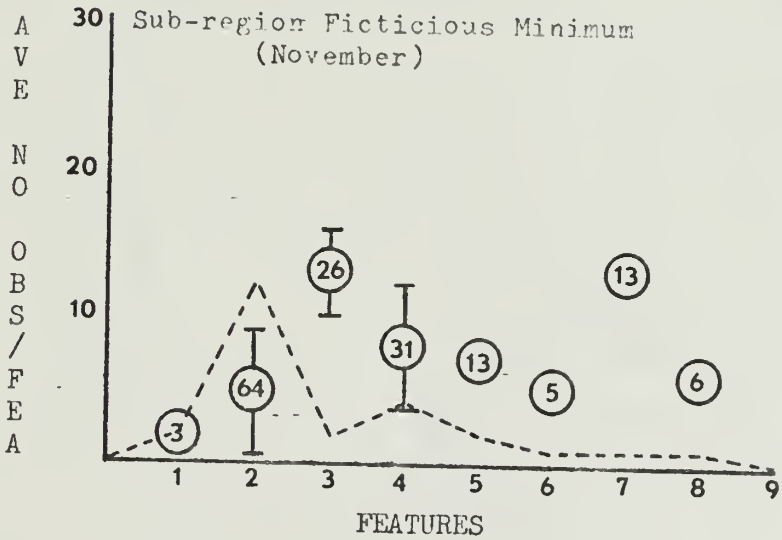
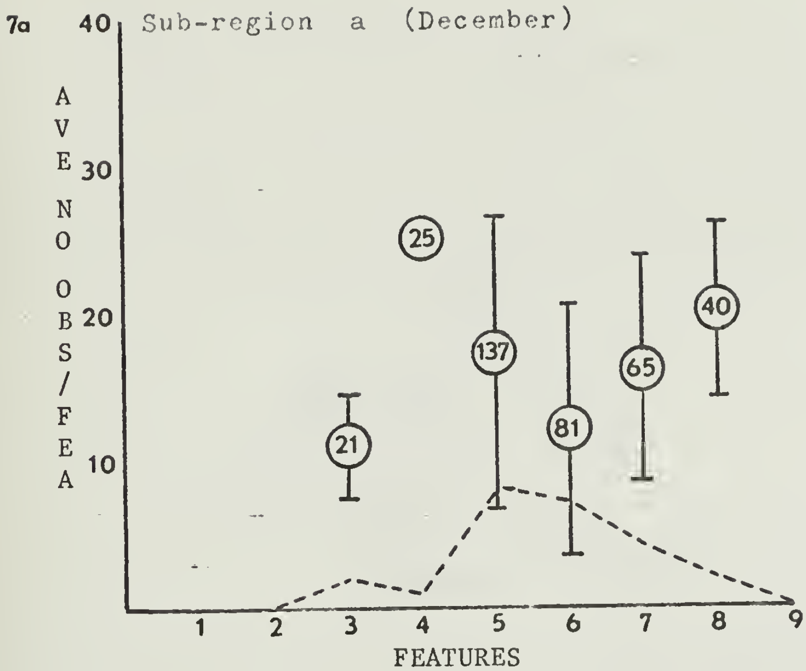


Figure 6: Monthly Average of the Number of Observations per Feature vs Features (November)



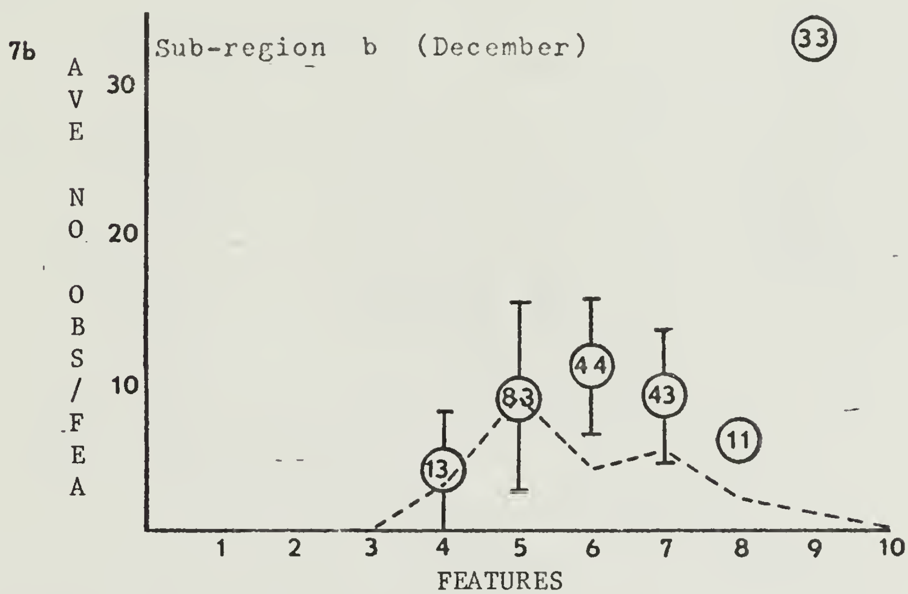
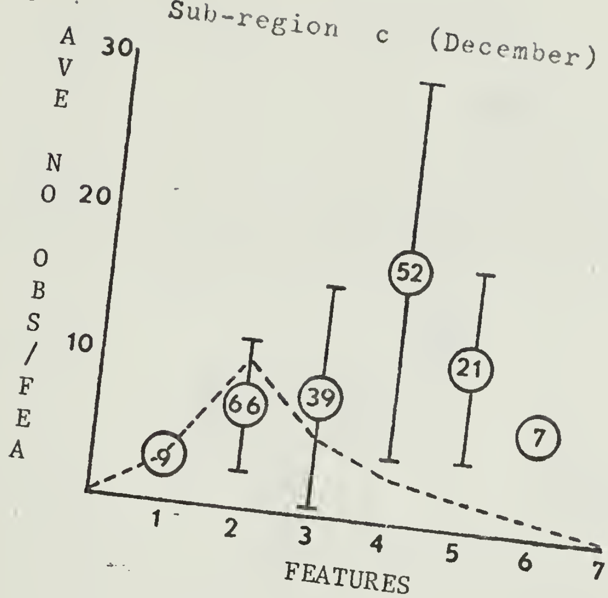


Figure 7: Monthly Average of the Number of Observations per Feature vs Features (December)

7c



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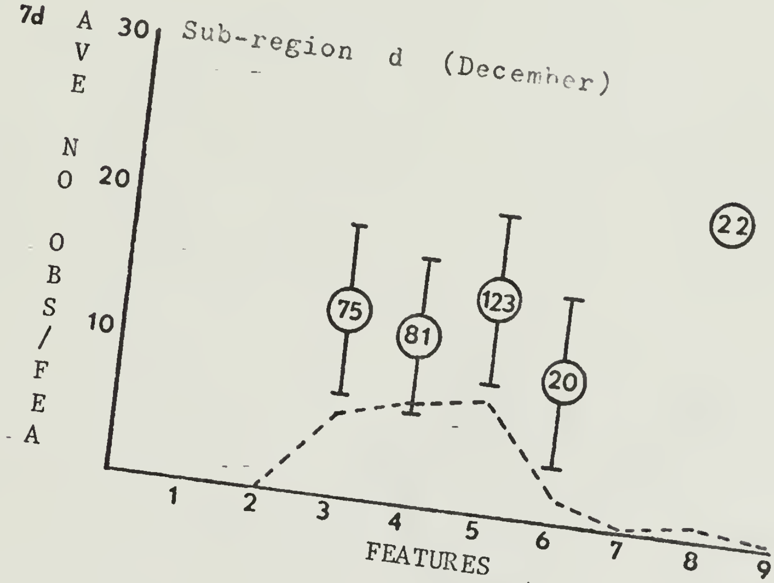
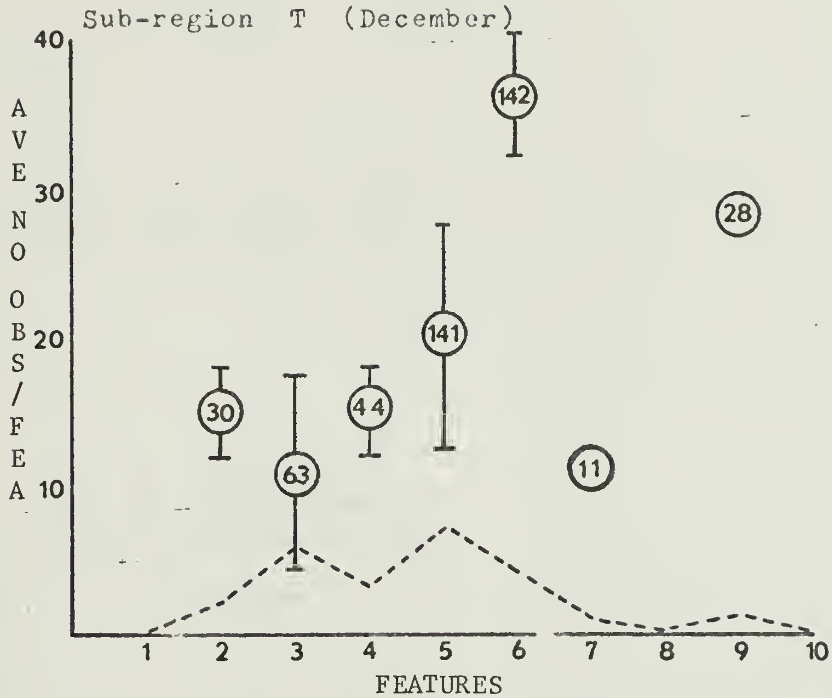


Figure 7: Monthly Average of the Number of Observations per Feature vs Features (December)

7e



7f

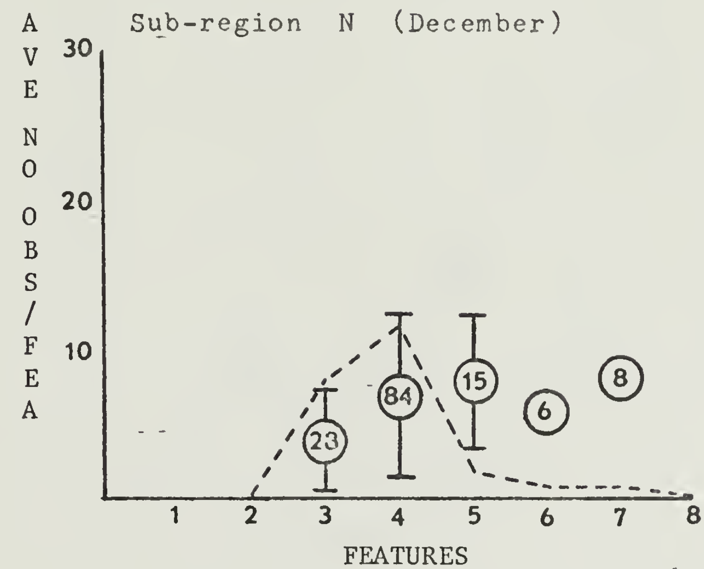
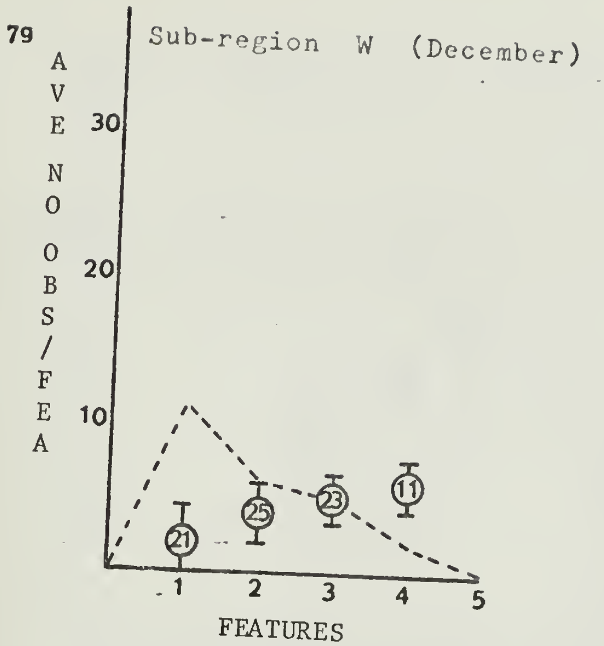


Figure 7: Monthly Average of the Number of Observations per Feature vs Features (December)



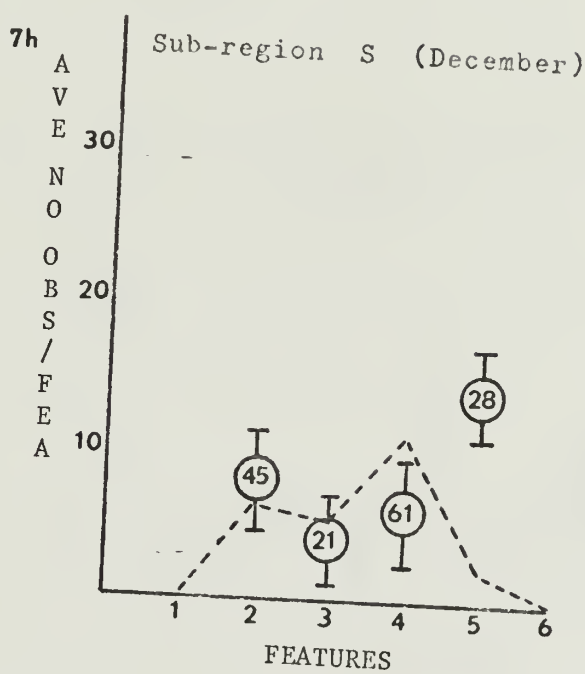
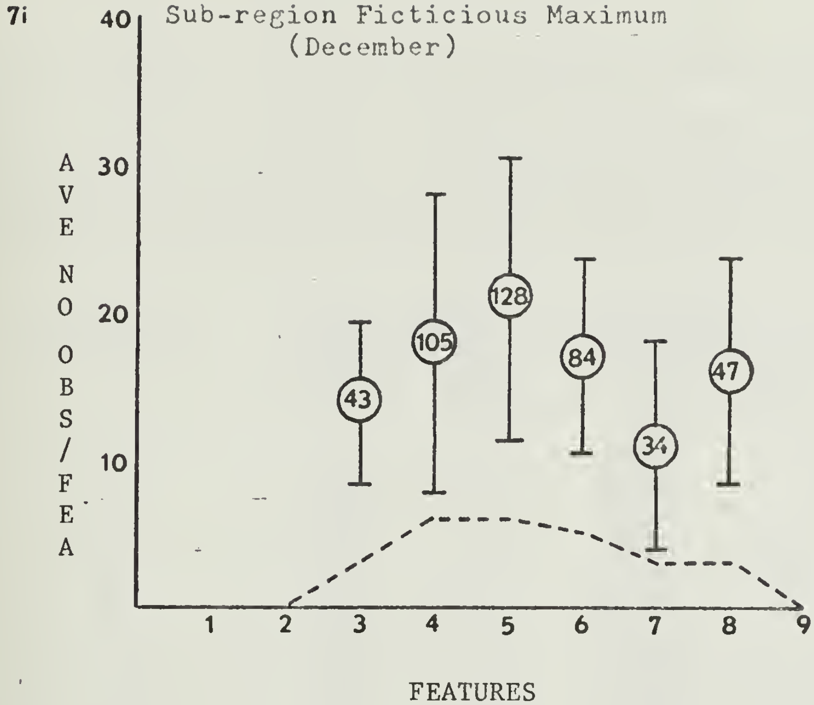


Figure 7: Monthly Average of the Number of Observations per Feature vs Features (December)



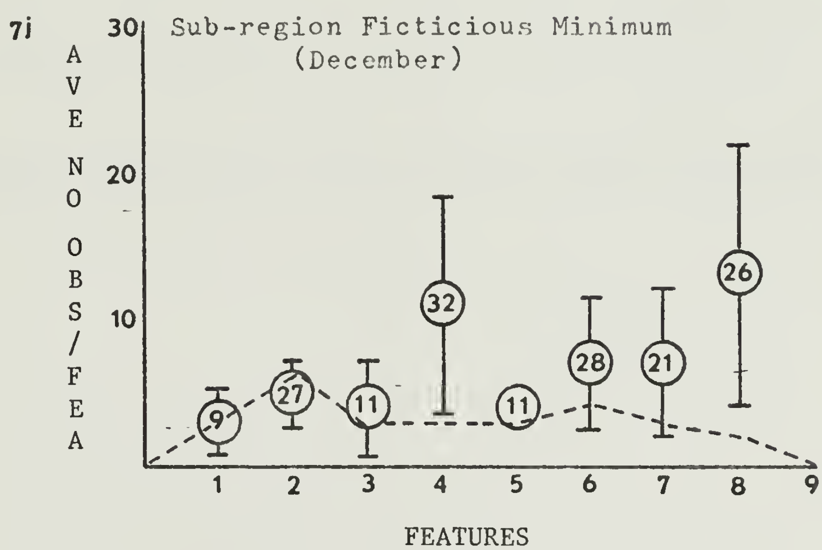


Figure 7: Monthly Average of the Number of Observations per Feature vs Features (December)

TABLE III

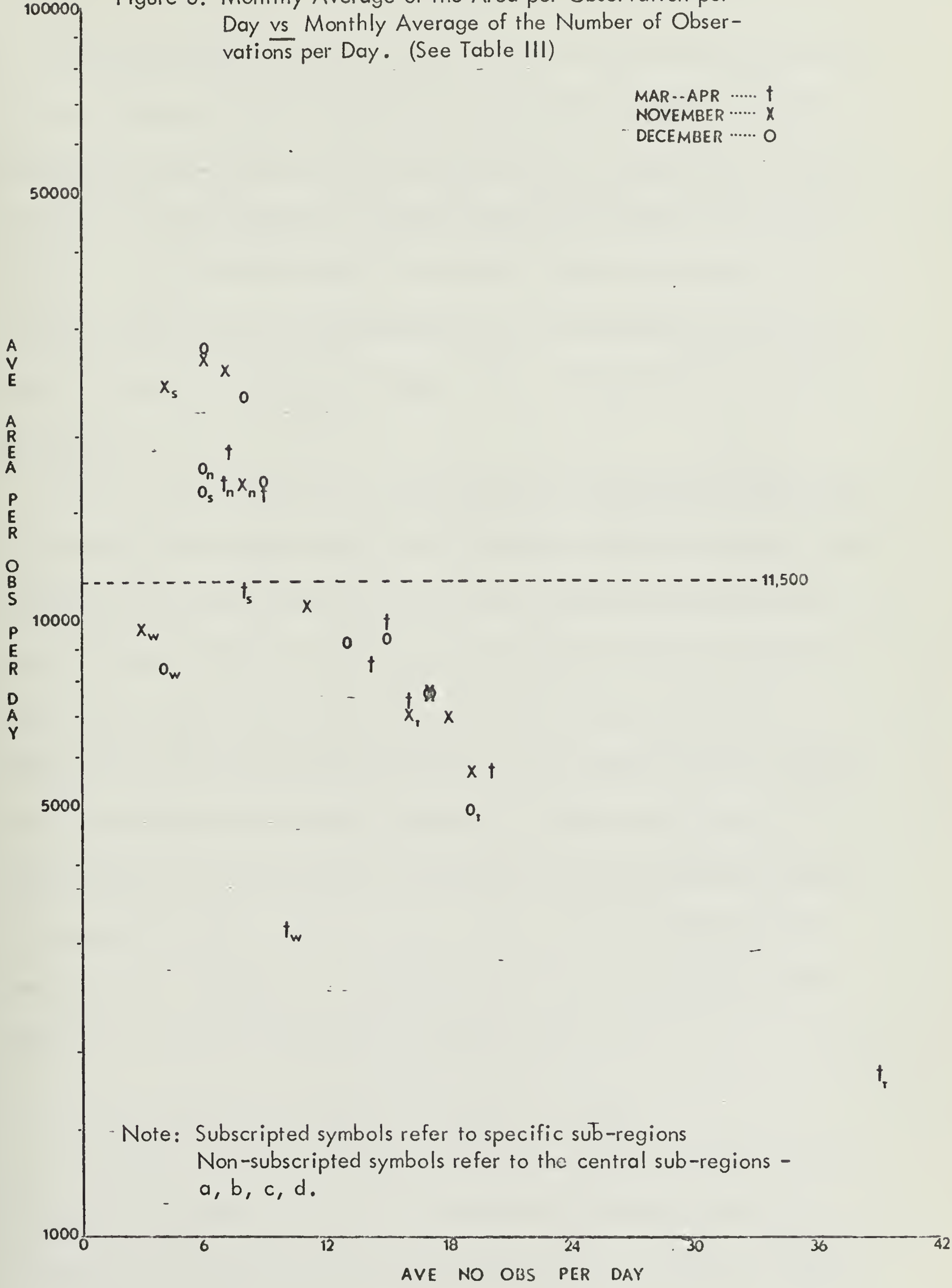
Monthly Average of the Daily Values for the Average Area per Observation and for the Average Number of Observations in Each Sub-region; as well as in Two Ficticious Sub-regions as Defined. (Data plotted in Figure 8).

SUB-REGION	MARCH-APRIL		NOVEMBER		DECEMBER	
	Ave.Area/ Obs.	Ave.# Obs.	Ave.Area/ Obs.	Ave.# Obs.	Ave.Area/ Obs.	Ave.# Obs.
a	7472	16	6969	18	9353	15
b	9976	15	10616	11	16979	9
c	16186	9	25642	7	23397	8
d	8592	14	7677	17	9243	13
T	1853	39	7011	16	4967	19
N	16854	7	16548	8	17848	6
W	3167	10	9723	3	8413	4
S	11201	8	24043	4	16318	6
* Fic. Max.	5731	20	5746	19	7701	17
** Fic. Min.	18900	7	26719	6	27815	6

* Composite region, consisting of the average of the largest of the number of observations on each chart for the four central sub-regions (a,b,c,d).

** Composite region, consisting of the average of the smallest of the number of observations on each chart for the four central sub-regions (a,b,c,d).

Figure 8: Monthly Average of the Area per Observation per Day vs Monthly Average of the Number of Observations per Day. (See Table III)



Note: Subscripted symbols refer to specific sub-regions
Non-subscripted symbols refer to the central sub-regions - a, b, c, d.

C. EFFECT OF CONTINUITY ON THE OBSERVATION TO FEATURE RELATIONS

As stated previously, continuity was not the determining factor in the analyses, but it was considered. When there were few data and when these did not conflict with patterns determined previously, continuity was used in shaping analysis features. As a result, comparing data density to analysis features is necessarily biased by the continuity. As an extreme example, on one chart six features could appear in a sub-region based on twenty-two observations; the next consecutive chart based upon continuity could have six features in that sub-region, although there were only five observations.

In order to see just what effect continuity had on the relationship between analysis features and data density and distribution, and how extensively continuity biased the results of this study, selected sub-regions were re-analyzed removing all influence of continuity, therefore using analyses which depended entirely on the observations actually present. After these analyses were made, the average number of observations per feature was plotted against the number of features which appeared. The relationship between the number of observations present and the number of features analyzed was good for those areas which showed a good relationship using the original data which included continuity; and poor where the relationship was poor previously. Therefore, the relationship which exists as a result of the subjective method used in the present study appears to be valid.

D. EFFECTS CAUSED BY ADDING AND REMOVING DATA

To answer the question of whether adding or removing data will result in more or less analysis definition, one needs to look at the local conditions that exist. In an area such as the deep basin of the eastern side of the South China Sea, adding or

removing portions of the data had little effect since the water mass is relatively stable and sea surface temperatures vary little from day-to-day, only gradually becoming colder or warmer as the seasons change. However, off the coast of Vietnam and in the Tonkin Gulf, the water masses are very much disrupted by the presence of shallow water depths, runoff - especially in the Mekong and Red River Delta regions, surface current eddies, and small islands and shoals in the local area which cause perturbations in the SST isotherms. In these areas, adding or removing data very much affects the analysis detail.

E. ANALYSIS FROM OTHER SOURCES

Neither the oceanographic atlas [12] nor the operational analyses of FWC Guam showed the three-part division of the South China Sea indicated by this study. The atlas displayed isotherms which showed a cold region close to the coast of Vietnam but then indicated diagonal lines across the South China Sea with an orientation generally SW to NE. The FWC Guam analyses for the period available for comparison also showed a cold region along the Vietnam coast. However, as the isotherms moved away from the Vietnam coast, they crossed the South China Sea in an undulating wave pattern without regard for the land masses and shoal areas which intervened. (See Figures 9a and 9b).

The sea surface temperature analyses of FWC Guam appeared to be principally based on continuity. There seemed to be no correlation between the number of analysis features and the data density or distribution (indicated by dots in Figures 9 a and 9 b). For example, in the Tonkin Gulf region, Guam's analyses consistently showed one or two analysis features; whereas tl analyses of the present study showed an average of six features in the same region. (Only once in the period of comparison did the present analyses show as few as two features there).

In addition, Guam's analyses were characterized by smooth wave patterns which at times seemed to ignore sizable quantities of data. There did not appear to be any relationship between Guam's analyses of mixed layer dapth or below layer gradient and either the Guam SST analyses or the SST analyses of the present study.

Figure 9 a:

FWC Guam SST Anal

DATE: 8 APR 1969

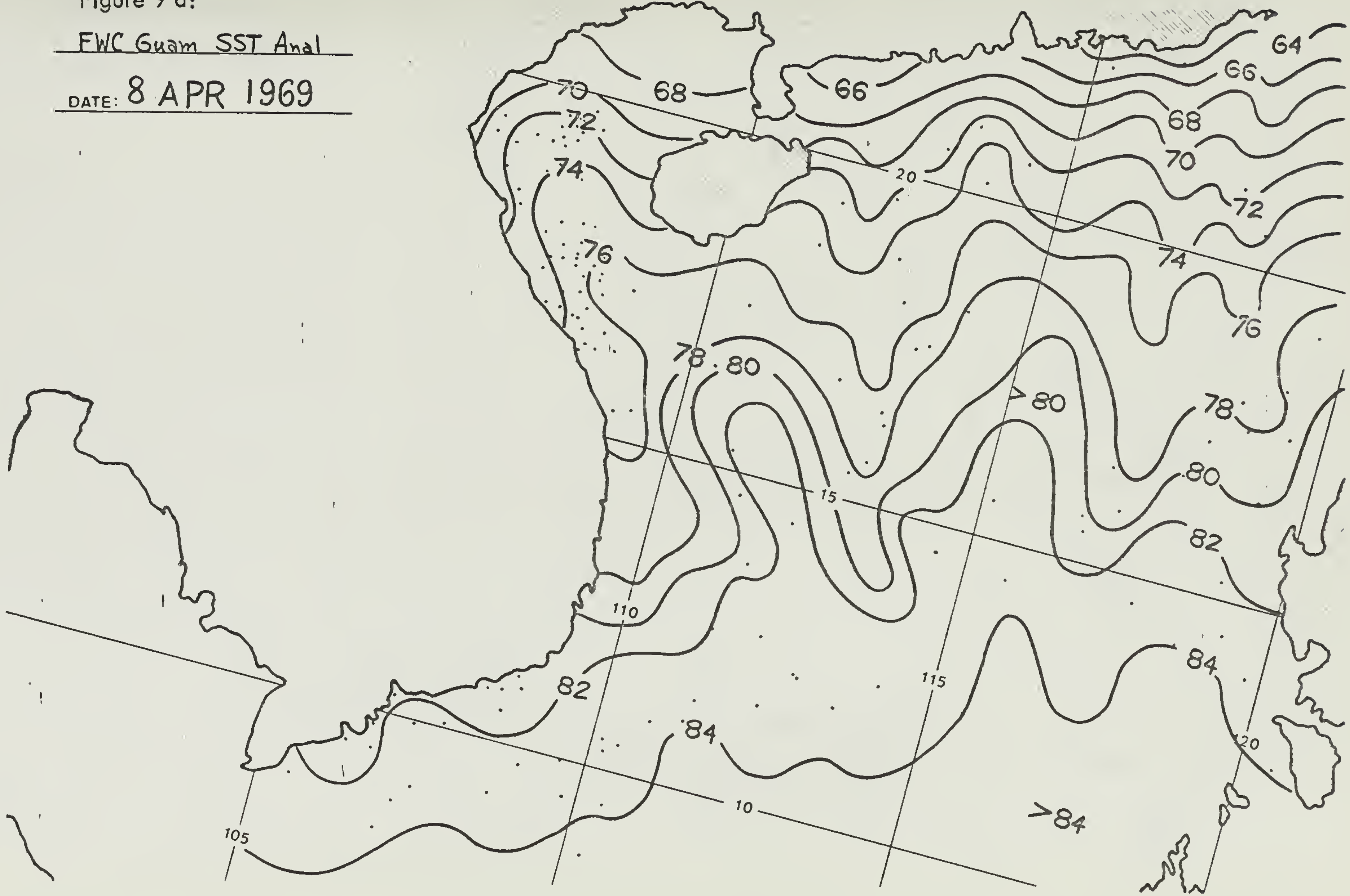
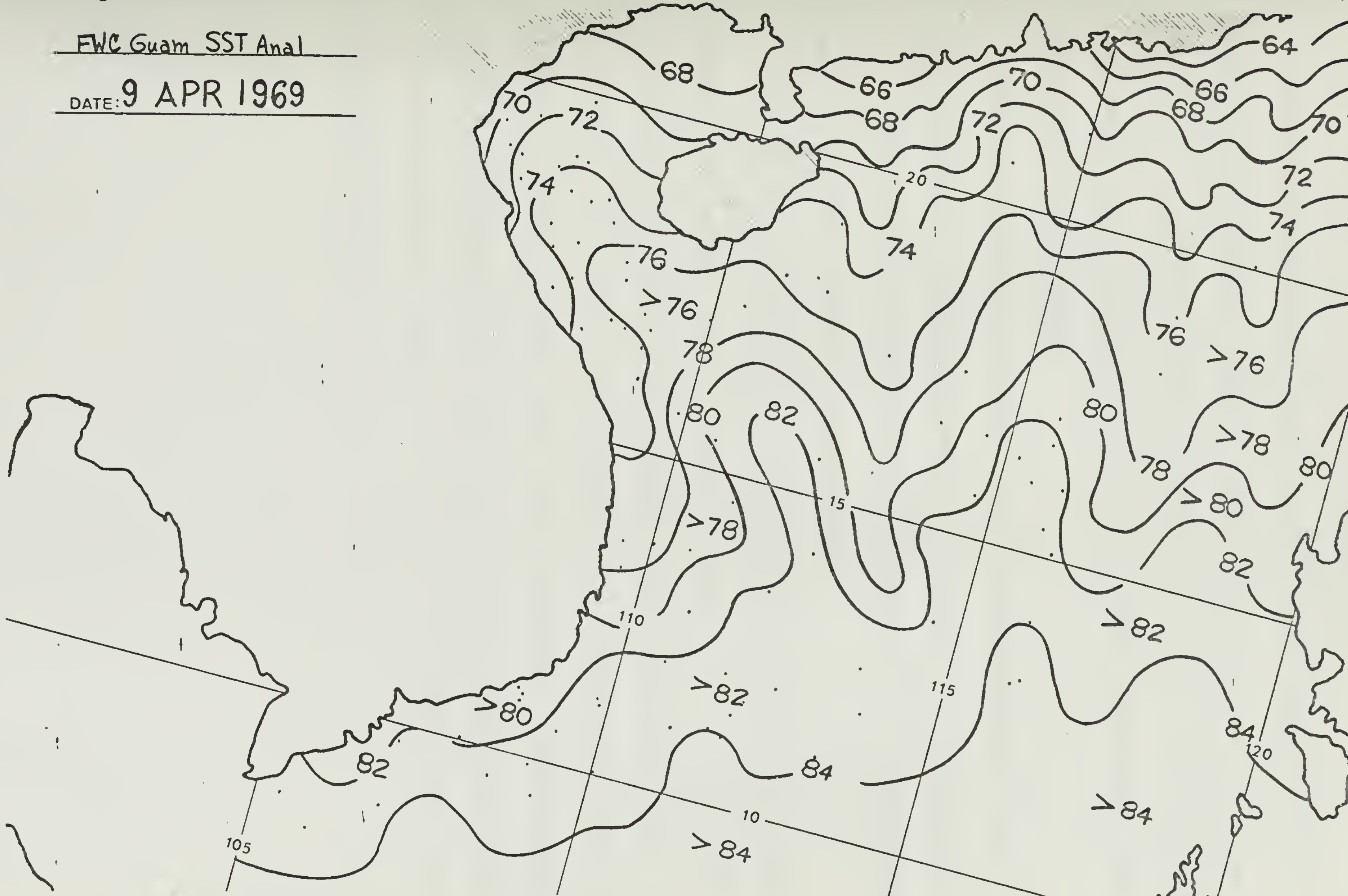


Figure 9 b:

FWC Guam SST Anal

DATE: 9 APR 1969



V. CONCLUSIONS

The subjective sea surface temperature analysis model for the South China Sea during the Northeast Monsoon season developed in this study showed a three-part division of the South China Sea into a cold western side, a warm central region, and a cold eastern side. Bottom topography and surface currents played a major role in delineating the analysis patterns.

There are two important factors which must be considered when deriving a relationship between the number of observations and the analysis features resulting from them. These factors are continuity, when the data density is small, and data distribution, when the observations are unevenly distributed.

When the area per observation was relatively small and the data were evenly distributed, the number of observations and the number of features which resulted from the analysis had a good linear relationship. As the area per observation increased and the data became unevenly distributed, the number of observations and the number of features had little or no relationship. In the latter situation, continuity had to be used to determine the analysis features and the extent to which continuity had to be used was directly related to the kind of relationship between the number of observations and the number of features which resulted.

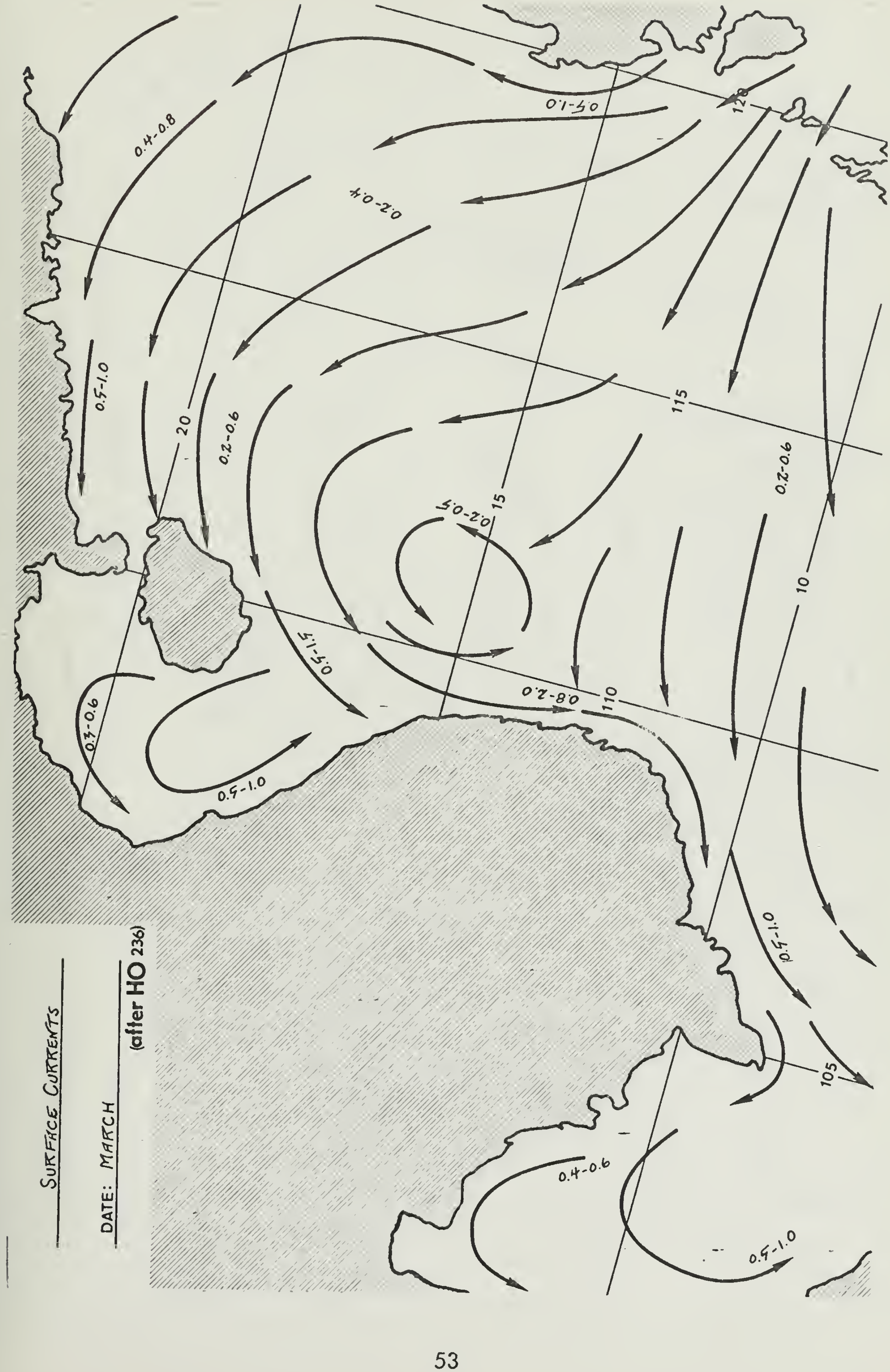
VI. RECOMMENDATIONS

Sea surface temperature analyses should be investigated for the Southwest (Summer) Monsoon season in order to complete a sea surface temperature analysis model for the South China Sea for both monsoon seasons.

The number of sea surface temperature observations available as a result of the increased shipping activity in the South China Sea during the last five years should provide an excellent data base to work out more specific relationships between the number of observations and the analysis features.

Analysts should use underlays of bottom topography and surface currents while analyzing sea surface temperatures in the South China Sea.

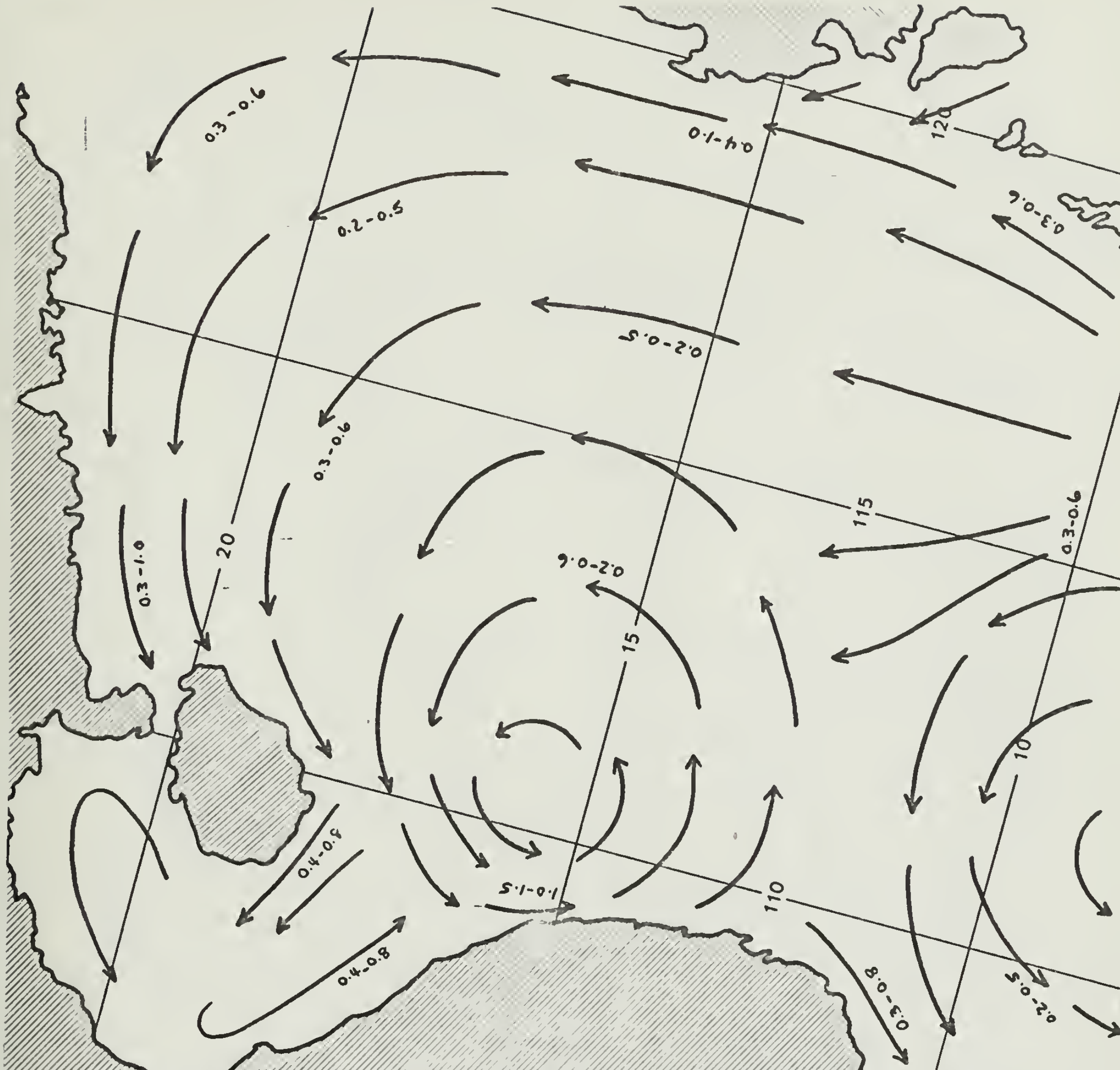
APPENDIX A



SURFACE CURRENTS

DATE: MARCH

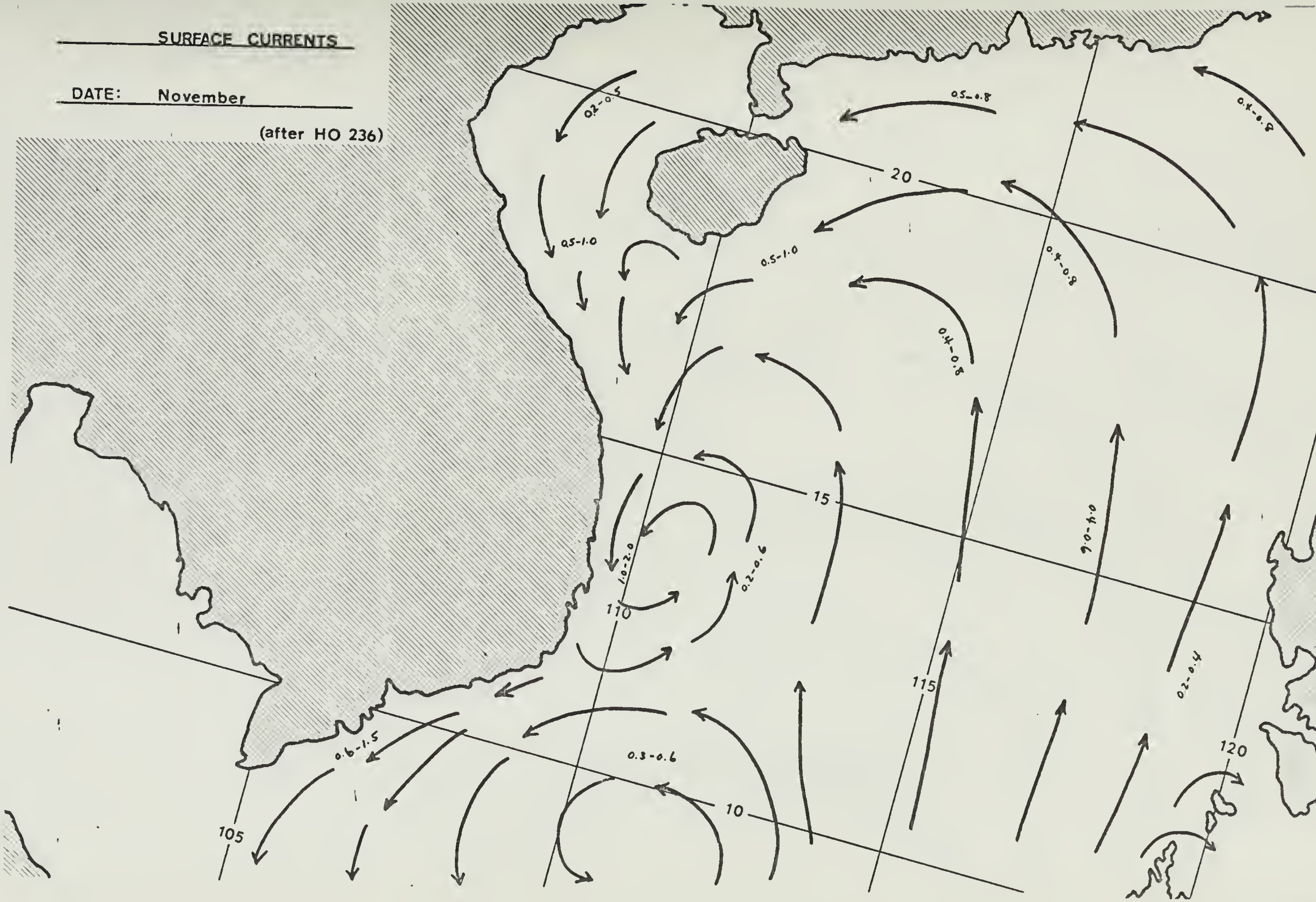
(after HO 236)

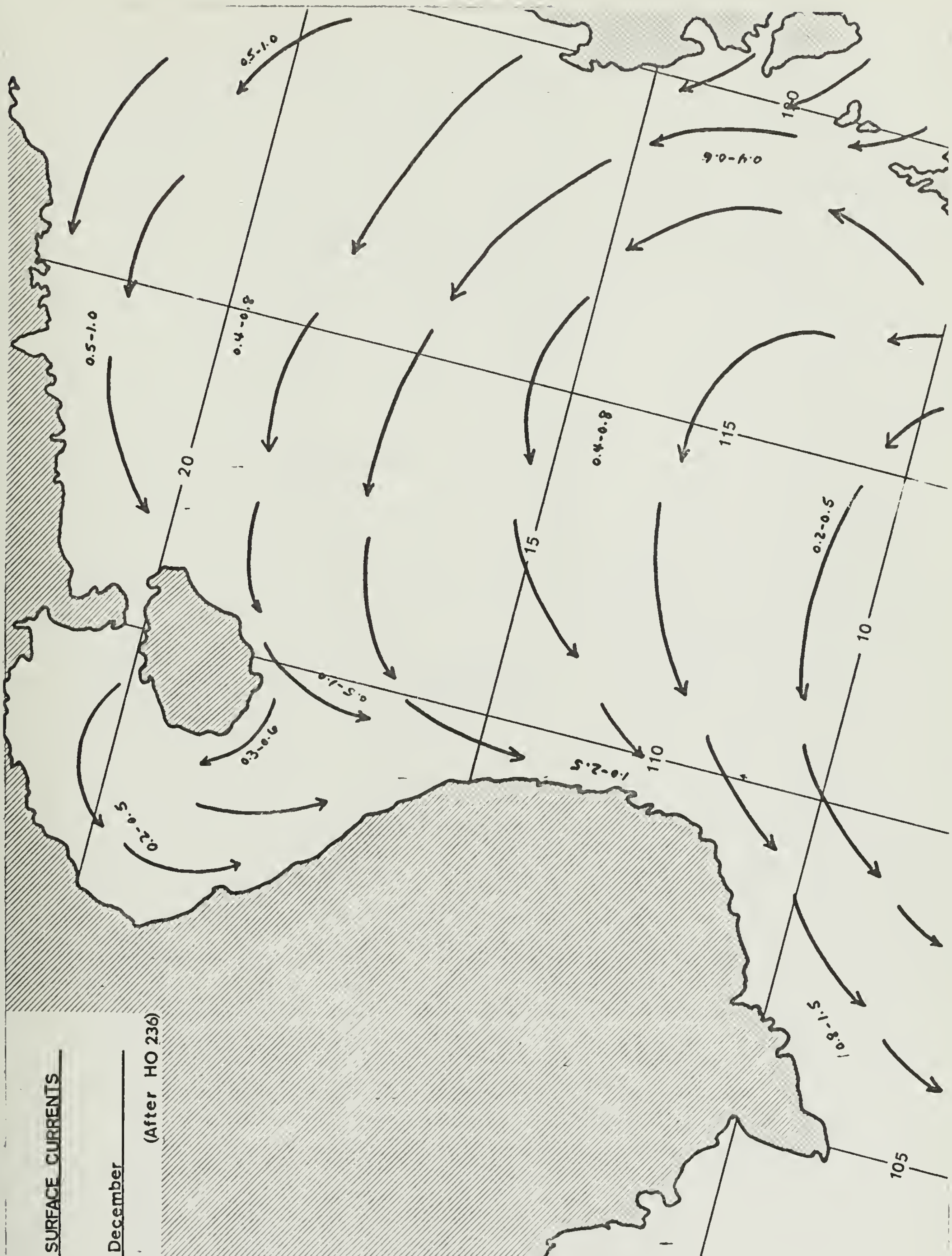


SURFACE CURRENTS

DATE: APRIL

(after HO 236)

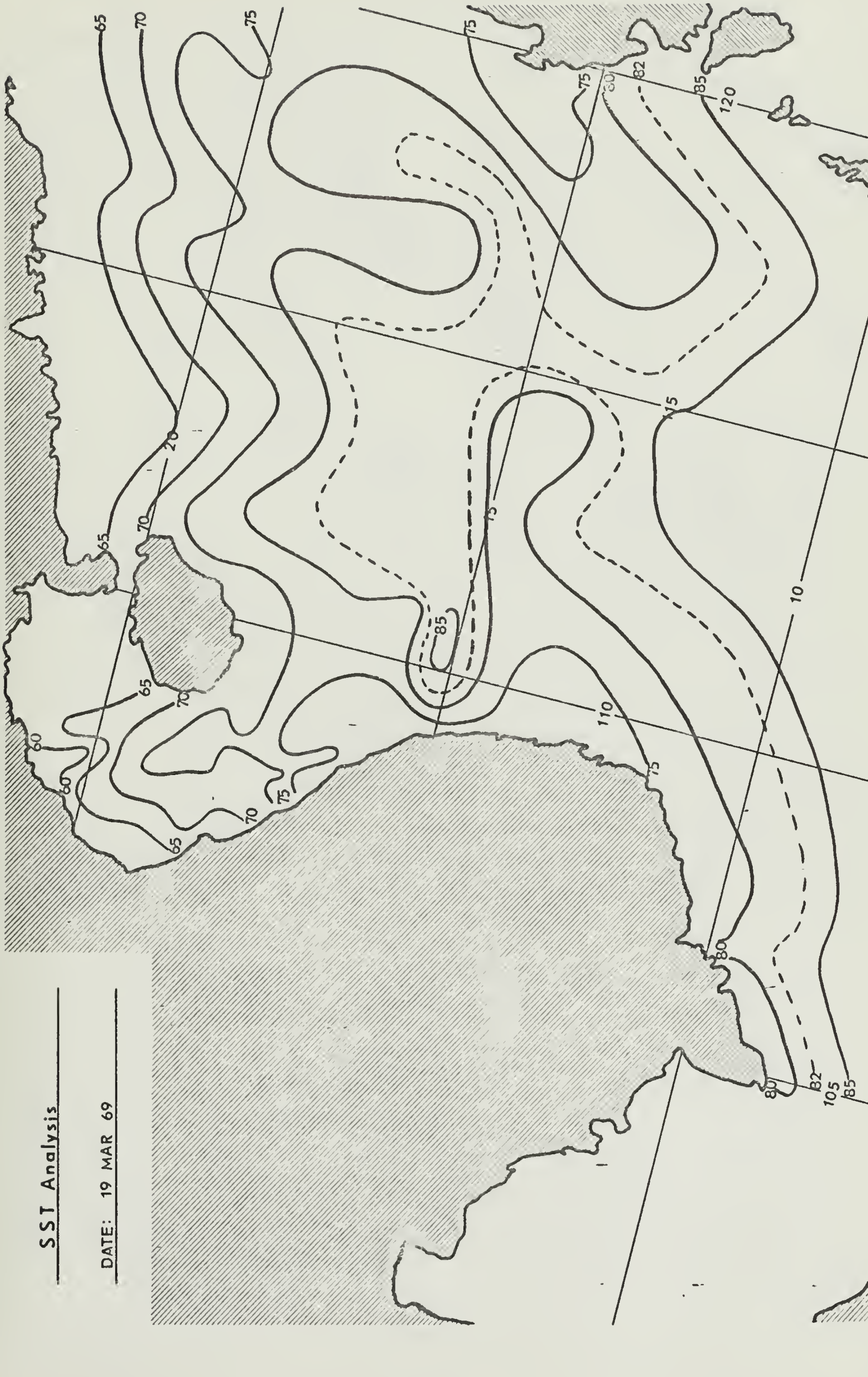

SURFACE CURRENTS
DATE: November
(after HO 236)
0.2-0.5
0.5-1.0
0.5-1.0
0.5-0.8
0.4-0.8
0.4-0.8
0.4-0.8
0.4-0.6
0.2-0.4
1.0-2.0
0.2-0.6
0.3-0.6
0.6-1.5
20
15
10
105
110
115
120


SURFACE CURRENTS
DATE: December
(After HO 236)
0.5-1.0
0.4-0.8
0.4-0.6
0.5-1.0
0.4-0.8
0.2-0.5
0.5-1.0
0.3-0.6
1.0-2.5
0.2-0.5
0.8-1.5
20
15
10
120
115
110
105

APPENDIX B

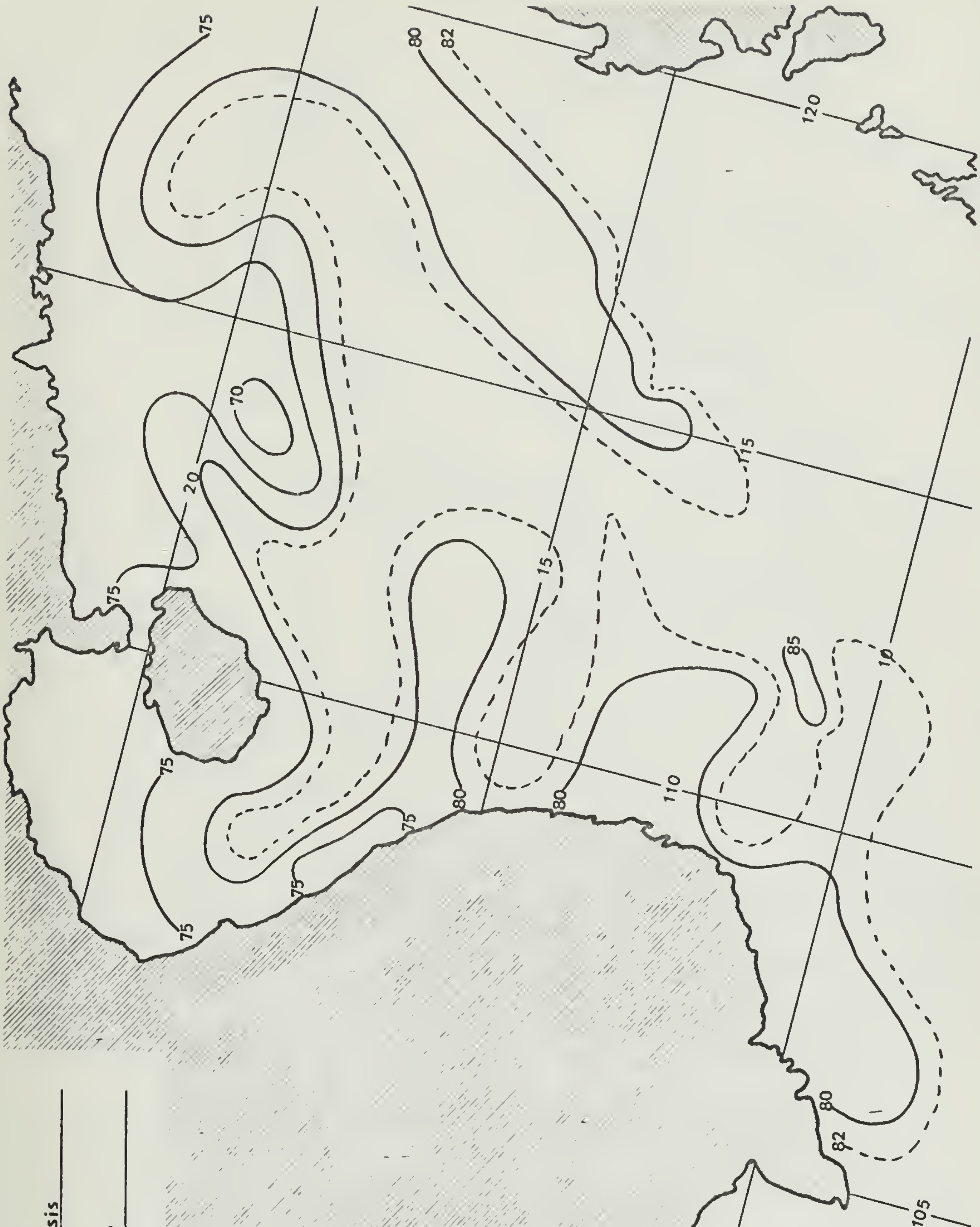
SST Analysis

DATE: 13 MAR 69


SST Analysis
DATE: 19 MAR 69
65
70
75
80
82
85
60
120
105
110
20
15
10

SST Analysis

DATE: 6-7 NOV 69


SST Analysis
DATE: 25 NOV 69
75
80
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120
70
20
15
115
75
15
85
10
75
110
80
80
75
75
75
80
82
105

SST Analysis

DATE: 3 DEC 69

SST Analysis

DATE: 20 DEC 69

APPENDIX C

CALCULATION OF THE AVERAGE AREA PER OBSERVATION

The average area per observation for each monthly period was calculated by the following method:

1. The area per observation for each sub-region for each chart was obtained by taking the area of the sub-region and dividing by the number of observations in that sub-region for that chart. (There were 24 charts for each monthly period.)

$$X_i = \frac{\text{Area}}{\text{No. of Observations}} = X_1, X_2, X_3, \cdots\cdots X_{24}$$

2. The daily values for the area per observation were averaged for the monthly period.

$$\overline{X} = \frac{1}{24}\sum_{i=1}^{24} X_i = \frac{\text{Area}}{24}\sum_{i=1}^{24}\frac{1}{(\text{No. of Observations})_i}$$

Example : X_i = Area/No. of Observations

$\overline{X}$ = Average Area/No. of Observations

Area = 100 sq. n. m.

No. of Obs. = 5, 10, 20, 10, 5

$$\overline{X} = \frac{100}{5}\sum_{i=1}^{5} (.2+.1+.05+.1+.2) = (20)\ (.65)$$

$\overline{X}$ = 13 sq. n. m.

The average area per observation (for the five-day period of the example) is 13 sq. n. m.

The average number of observations (for the five-day period of the example) is 10.

The average area per observation was not calculated by taking the total area and dividing by the monthly average of the observations. Referring back to the example,

this method would result in a value of 10 sq. n. m. for the average area per observation for the five-day period.

The reason that the average area per observation was calculated by the method described above was a by-day average of the area per observation was more representative of what the analyst faces in the spatial distribution of data to be analyzed.

BIBLIOGRAPHY

1. Fleet Weather Central Guam, "South China Sea", Oceanographic Outlook, p. A-1, March 1969.

2. ____________, "South China Sea", Oceanographic Outlook, p. A-1, April 1969.

3. ____________, "South China Sea", Oceanographic Outlook, p. B-1, November 1969.

4. ____________, "South China Sea, Oceanographic Outlook, p. B-1, December 1969.

5. Navy Weather Research Facility Report NWRF 12-0669-144, The Diagnosis and Prediction of SEASIA Northeast Monsoon Weather, p. 1-66, June 1969.

6. ____________, Report NWRF 36-0667-126, Analysis and Forecasting of Sea-Surface Temperature (SST), by P. M. Wolff, L. P. Carstensen, and T. Laevastu, p. 1-48, June 1967.

7. U. S. Naval Hydrographic Office, Currents in the South China, Java, Celebes and Sulu Sea, (H. O. Pub. No. 236), 1945 (Reissued 1965).

8. ____________ Marine Geography of Indochinese Waters, (H.O. Pub. No. 754), 1951.

9. U. S. Naval Oceanographic Office Informal Manuscript 67-5, Temperature, Salinity, and Density of the World's Seas: South China Sea and Adjacent Gulfs, by P. E. LaViolette and T. R. Frontenac, p. 1-134, February 1967.

10. ____________ Informal Manuscript 67-10, Oceanographic Cruise Summary South China Sea, by S. G. Tooma, Jr. and H. Iredale, III, p. 1-20, February 1967.

11. ____________ Informal Report 68-67, Oceanographic Cruise Summary CamRanh Bay-Nha Trang-Poulo Condore Group, by D. E. Kenney, p. 1-24, September 1968.

12. ____________ Special Publication SP-99, Monthly Charts of Mean, Minimum, and Maximum Sea Surface Temperature of the Indian Ocean, by P. E. LaViolette and C. Mason, p. 1-48, 1967.

13. University of Miami Scientific Report, The Structure of Sea Surface Temperatures in Monsoonal Areas, by Walter Düing, p. 1-25, April 1970.

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13. ABSTRACT

A daily subjective analysis of sea surface temperatures in the South China Sea for three monthly periods during the Northeast (Winter) Monsoon was performed. The analysis model developed showed a three-part division of the South China Sea into a cold eastern side, a warm central region and a cold western side. Bottom topography and surface currents played a major role in delineating analysis patterns. The relationship between data density and distribution and analysis detail was found to be affected adversely by continuity, when data density was small, and by the distribution of the observations, when the data were unevenly distributed. When the area per observation was relatively small and the data were evenly distributed, the number of observations and the number of analysis features which resulted from the analysis had a good linear relationship.

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South China Sea						

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